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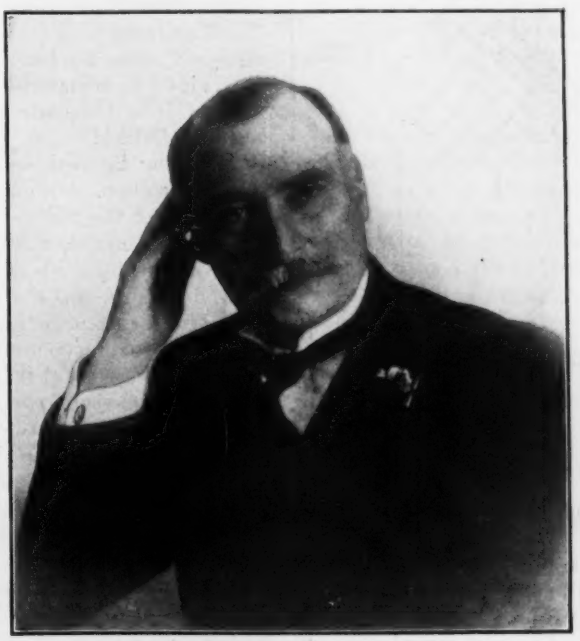
The Municipal Engineering Works of San Francisco

A Description of Notable Engineering Works of the City Engineering Department of San Francisco

Many of the engineers who will visit San Francisco this year to see the marvelous international exposition which has been there created will desire to see something also of the city's remarkable engineering works. In no great city of the world has widespread destruction ever been followed by such rapid and complete rebuilding; and with this rebuilding of the city's factories and warehouses and office buildings and dwellings has gone on the reconstruction of its great public works.

It has seemed to us that an adequate presentation of the important works carried on by the city engineering department of San Francisco would be a useful guide to engineers who will visit that city this year and would be of wide interest, also, to those unable to enjoy that privilege, since many of these great works are novel and unprecedented in their character.

Through the courtesy of Mr. M. M. O'Shaughnessy, City Engineer of San Francisco, we are able to present in the series of articles on the following pages what is practically an official description of the city's great engineering works. The articles have been written by Mr. A. J. Cleary, Assistant City Engineer, by direction of Mr. O'Shaughnessy.



M. M. O'SHAUGHNESSY
City Engineer of San Francisco

The portrait of Mr. O'Shaughnessy on this page will interest all who know the wide reputation he has gained in the field of hydraulic engineering. Mr. O'Shaughnessy is a native of Ireland, attended Queen's College, Cork, and Queen's College, Galway, and graduated with honors from the engineering course of the University of Dublin in 1884. Shortly afterward he came to America. After a brief period of service in the engineering force of the Southern Pacific Co. he entered the field of hydraulic engineering. In 1892 he was chief engineer of the California Mid-Winter International Exposition, held in San Francisco, and later became chief engineer of the Mountain Copper Co. and other important corporations.

In 1899 he went to Hawaii and for seven years was engaged in planning and constructing the great plants used for water-supply and irrigation on the Sandwich Islands sugar plantations. A valuable paper by Mr. O'Shaughnessy describing these engineering works was published in our issue of Apr. 15, 1909.

Returning to California in 1907, Mr. O'Shaughnessy resumed his practice as a consulting engineer and had charge of many important works, such as those of the Southern California Mountain Water Co. in the mountains back of San Diego, the Port Costa water-works, and the works of the Spreckels Sugar Co.

A very important part of the reconstruction of San Francisco has been its civic reconstruction. The men who joined together with with wonderful courage to build a new San Francisco on the ashes of the old realized that it was essential to the city's prosperity that its great public works should be carried on in a businesslike manner and by officials who could be trusted to be faithful to the city's interests. The most important of these great works are those in connection with the new water-supply for the city to be brought from the Hetch Hetchy Valley in the distant Sierra Mountains. With foresight of the greatness of this task, Mr. O'Shaughnessy was selected as City Engineer of San Francisco and assumed office Sept. 1, 1912.

San Francisco's Auxiliary Water-Supply for Fire Protection

On Apr. 17, 1906, San Francisco's bonded indebtedness was less than that of any other city of equal size in the United States. Despite the fact that previous to that time there had been much adverse criticism of the city's government, the general financial condition, due to the city's unexcelled natural resources and rapid development, was more than prosperous.

On the morning of Apr. 18 a severe earthquake was experienced along the coast of central California. The shock broke the water mains leading into San Francisco from San Mateo County, leaving no ready means of defense against the several small fires which had been

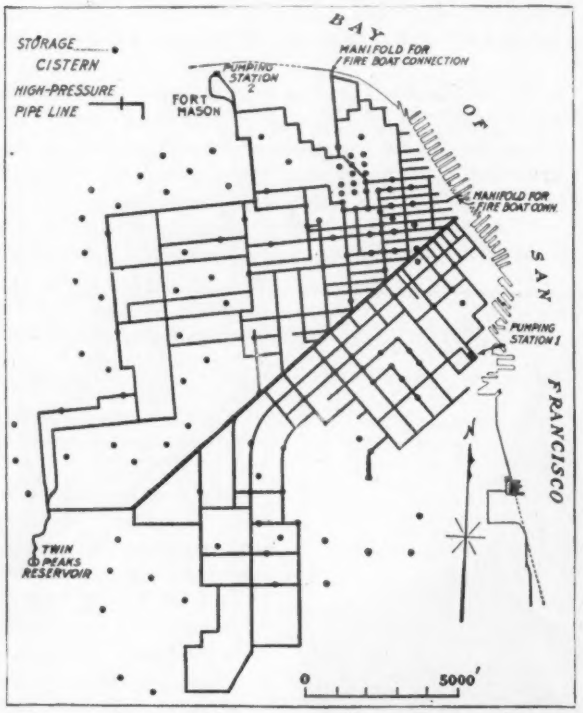


FIG. 1. THE FIRE-PROTECTION WATER-SUPPLY SYSTEM OF SAN FRANCISCO

started by wires that became crossed during the half-minute period of vibration. Within a few hours it was evident that the efforts of the fire department to control the various fires by pumping water from the bay or from sewers would be futile. The United States military authorities stationed at the Presidio were appealed to and they endeavored to check the conflagration by dynamiting buildings in its path. This method also proved ineffective. For three days the fire raged, leaving thousands homeless and destroying property to the value of approximately $325,000,000. Nothing daunted by this experience and impressed with the city's need of fireproof building construction and more adequate fire protection, the débris was immediately removed and the work of reconstruction begun. This has progressed steadily until a new city, architecturally and structurally more perfect, has replaced the one that was destroyed.

In rebuilding the business district much more attention has been given to structural analysis and detail. While it is true that a few poorly constructed buildings were completely destroyed by the earthquake of 1906, and several well constructed buildings were damaged, this loss was infinitesimal when compared with that caused by the subsequent fire. To guard against a similar disastrous conflagration an auxiliary water-supply system for fire protection has been installed. In its design and construction every provision has been made for vibration, and it is predicted that should another severe earthquake occur —a possibility which for the next fifty years is remote— the auxiliary system will not be badly damaged.

As at present constructed, the fire-protection system comprises two distinct units. One is a high-pressure pipe distribution supply with its appurtenant reservoirs and pumping stations. The second is a series of independent cisterns specially designed to withstand severe earthquake shocks. There are in addition two fireboats for the protection of the water front and shipping interests.

The area protected by the high-pressure system exceeds eight square miles, which includes the business and manufacturing districts, and the more densely settled residential section. Due to the city's irregular topography it was necessary, in order to secure fairly uniform pressure in both high and low districts, to divide the protected area into two zones, each supplied from an independent distribution reservoir. Both zones, however, can be connected to the main supply reservoir. The upper zone includes all districts whose elevation is greater than 150 ft. This is supplied from a 500,000-gal. steel tank situated on Clayton St., near 17th St., at an elevation of 490 ft. It is 55 ft. in diameter by 29 ft. ½ in. high, and being situated in a residential district the reservoir is ornamentally finished.

Adjoining the tank is a pump and valve house. The pumping station, which is intended to supply water from the mains of the Spring Valley Water Co. to the Twin Peaks Reservoir, has a capacity of 1400 gal. per minute. The equipment consists of two multi-stage turbine pumps each driven by an alternating-current electric motor. Power for the motors is supplied from two distinct sources to provide for interruptions in service. The pumps are not intended for use at the occurrence of a fire, but merely to maintain the supply in the main reservoir above.

Fresh water is furnished to the lower zone from the Jones St. reservoir, at an elevation of 335 ft., located near the corner of Jones and Sacramento St. The reservoir is cylindrical, of reinforced concrete, 60 ft. inside diameter and 35 ft. 10 in. high. Its capacity is 750,000 gal. To provide for expansion and contraction, as well as to allow for mobility if subjected to earthquake shock, a special type of expansion joint was provided between the bottom slab and the cylindrical wall.

This joint is of the sliding type, and by its use the cracks so common at the base of reinforced-concrete reservoir walls have been obviated. A raised rim is provided inside the joint to prevent excessive movement of the cylindrical shell along the bottom slab, in case of earthquake. A circumferential steel angle was placed on the lower interior corner of the wall to hold in place the bottom ends of vertical reinforcing channels.

A detail of the joint is shown in Fig. 2. In its construction the concrete in the base slab was first poured, and the surface on which the wall would rest was smoothed with a cement-mortar finish. To prevent adhesion between the concrete base slab and concrete wall, a coating

of asphalt paint was next applied. Forms for the wall were then built, and the concrete poured. When the forms were removed, oakum was tightly calked into the bottom of the joint as shown on the drawing, and the remaining space filled with liquid asphalt. This joint has proven very satisfactory and permits no leakage.

Like the Clayton St. tank, the Jones St. distributing reservoir is artistically finished to harmonize with its residential surroundings. The architecture is of Mission style. The external lines are pleasing, with a simple molded base, an entasis on the side walls, and a cornice

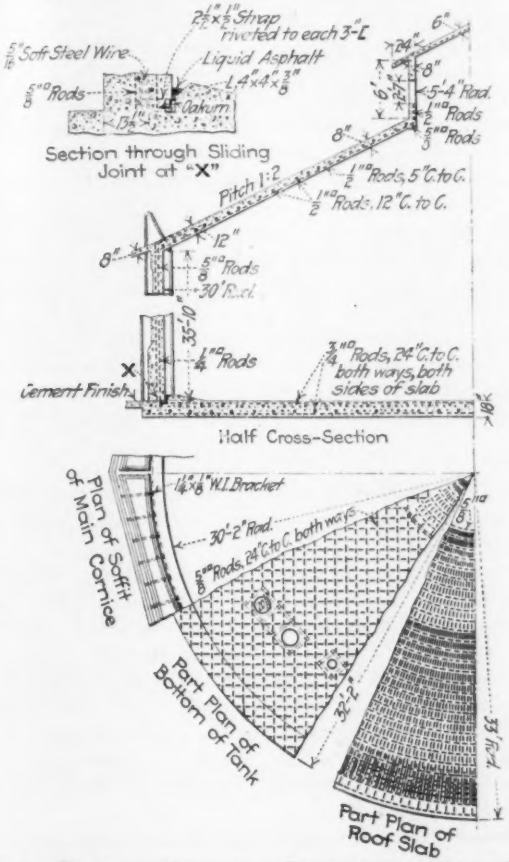

Section through Sliding Joint at "X"
Half Cross-Section
Plan of Soffit of Main Cornice
Part Plan of Bottom of Tank
Part Plan of Roof Slab

FIG. 2. PLAN AND SECTIONAL ELEVATION OF JONES ST. RESERVOIR AND DETAIL OF SLIDING JOINT

capping, the severity of which is diminished by 12 lustertile inserts, one between each pair of triglyphs that mark the corners of the pyramidal roof. The white cement finish of the walls contrasts in a pleasing manner with the red tile roof, and the whole structure is an ornament rather than a disfigurement to its neighborhood.

When necessary to operate the system at a pressure higher than 150 lb. per sq.in. at the hydrant, which is provided in each zone from the separate distributing reservoir, by opening a valve at the Clayton St. pumping station both zones can be connected to the main supply reservoir, located near the summit of the Twin Peaks range, at an elevation of 760 ft.

This main supply reservoir is of reinforced concrete. It is oval shaped, having a length of 375 ft. and a width of 280 ft. On the sides of the two compartments into which it is divided the concrete was poured quite wet between longitudinal side forms 12 ft. apart, on top of which 3x12-ft. covers were placed one at a time as the concrete was poured, in order to hold it to the slope. Concrete for the sides and bottom of the reservoir, which are 8 and 6 in. thick, respectively, was 1:2:4, waterproofed with hydrate of lime.

Compartments are separated by a narrow buttressed wall of concrete heavily reinforced. The stability of the wall depends on the condition that when one compartment is full and one empty, there must be no overturning movement due to an accumulation of water under the floor of the reservoir. Such an accumulation is prevented by a system of over 10,000 ft. of 6-in. and 8-in. ironstone pipe subdrain under the reservoir lining. Two springs encountered during construction were drained by this system.

Most of the reservoir is built on an excavated area of chert and sandstone. Where fill was necessary it was made by scraping in fine rock and clay mixed, depositing this in 4-in. layers and thoroughly compacting each layer by rolling with a 5-ton steam roller. Before placing this fill, all soil and soft material were removed from the area that was to be covered. This surplus, together with the material excavated from the site, was removed beyond the roadway which surrounds the reservoir, covered with fertilized loam and planted to grass, thus giving added stability to the embankment.

Outlet pipes, which are used also for filling the compartments, are 20 in. in diameter. They are in tunnels 7 ft. high and 7 ft. wide in the clear, lined on the bottom with 6 in. and on the top and sides with 13 in. of 1:2:5 concrete reinforced. The overbreak was filled with spalls and 1:3:6 concrete. The tunnels are of such depth that the pipes in them will run full until the reservoir is entirely empty. The tunnels also contain 10-in. pipes connecting to the subdrains and to the sumps in front of the forebays, allowing the removal of any silt or mud that may collect in the reservoir bottom.

Regulating gates for each compartment consist of two 2x3-ft. sluice gates in the forebays, and a 20-in. gate valve on each outlet pipe. The water passes through four-mesh brass wire screens and the gates can be so regulated that in case of trouble with either main outlet pipe, water can be taken from either compartment through the other outlet pipe. For this purpose a 20-in. connection is provided between forebays and also between gate chambers. These connecting pipes are in tunnels and are embedded in the concrete which completely fills the remainder of the tunnel space.

When first constructed, considerable leakage occurred at the specially designed expansion joints. This leakage has been completely eliminated as later described in this article.

PUMPING STATIONS

For ordinary fires fresh water is better adapted than salt water as it causes less damage to perishable goods, and is as efficient in extinguishing flames. The system will, therefore, be operated with fresh water unless the supply is cut off by breaks in the mains due to earthquake or other contingency. In such an emergency, pressure in the pipes can also be maintained by two salt-water pumping stations, which are an integral unit of the auxiliary supply. Sites for the buildings were chosen at two locations miles apart in different parts of the city where a hard rock formation existed in proximity to the Bay shore

line. This precaution was taken because, in an earthquake, vibration is ordinarily less in areas where the foundation is rock. One station is located at Second and Townsend St., the other on the United States military reservation at Fort Mason. Both buildings are of heavily reinforced concrete with a steel frame and are designed to withstand severe earthquake shock. The Townsend St. station is in a manufacturing district where tall chimneys predominate. Special care was taken in designing roof trusses that would be unaffected by the impact of falling cornices or chimneys. Both stations are adaptations of the Mission style of architecture, ornamentally finished.

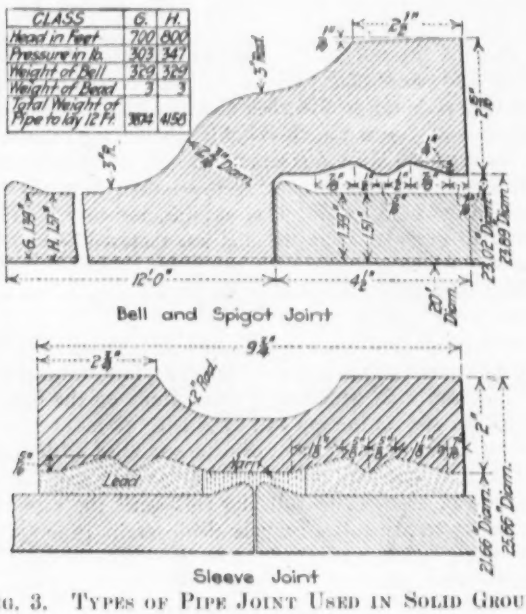

CLASS G. H.
Head in Feet 700 800
Pressure in lb. 303 347
Weight of Bell 329 329
Weight of Bead 3 3
Total Weight of Pipe to lay 12 Ft. 3634 4156
Bell and Spigot Joint
Lead
Yarn
Sleeve Joint

FIG. 3. TYPES OF PIPE JOINT USED IN SOLID GROUND AND SOFT GROUND

The equipment of the Townsend St. station consists of four Curtis turbine-driven centrifugal pumps, each capable of supplying 3000 gal. per minute at a pressure of 305 lb. per sq.in. They are of the noncondensing type, 750 hp., 1800 r.p.m. Eight 350-hp. Babcock & Wilcox boilers supply steam to the turbines. The remainder of the equipment comprises one 10-kw. electric-light engine, two feed pumps, two oil pumps, two feed-water heaters, with appurtenances. Six fresh-water reservoirs were constructed below the floor of the building in order that a supply of fresh water for the boilers could be maintained continuously, independent of the supply from the Spring Valley Water Co.'s mains. The fresh water and oil storage provided is sufficient to operate the entire station for 96 hours without receiving additional oil or water from outside the station. Space has been provided for the installation of two additional batteries of boilers and two additional pumps, should it be considered desirable at a later date to increase the capacity of the plant.

A reinforced-concrete suction conduit leads from beneath the pumping station down Townsend St. to the water front, where it connects to the bay below the level of low water. Through this the salt water is supplied to the pumps.

Two independent 20-in. cast-iron discharge pipes leading from the station to the 72 miles of main are laid, one on Second St. and the other on Townsend St., Stanford St. and Brannan St., so that an accident to either pipe will not involve the other.

The United States Government gave to San Francisco permission to construct Station No. 2 on the grounds at Fort Mason military post on condition that the city would supply all the electric current required on the reservation for lighting and other purposes. As the condensing type of engine is the more economical for continuous operation, but more expensive in first cost, the pumps chosen for Station No. 2 are convertible condensing or noncondensing. To economize in space, Stirling boilers were installed instead of Babcock & Wilcox. Otherwise the equipment is practically the same as for Station No. 1. As shown on Fig. 1, the two mains leading from the Fort Mason station, like the two pipes from the Townsend St. station, follow two independent routes, so that an accident to one will not affect the other.

Pumping station No. 1 is maintained with one battery of boilers under steam constantly, so that immediately upon the receipt of an alarm of fire the attendants are able to start one pump. In a test made by the chief of the fire department on the night of Aug. 12, 1913, fires were lighted under the remaining boilers and the entire service put into operation within 32 minutes after the first signal was received. The Fort Mason station has also been tested in this manner and the results were substantially the same as at Pumping Station No. 1.

PIPE-DISTRIBUTION SYSTEM

Pipe in the distribution system is of cast iron, varying in diameter from 20 to 10 in., with leaded joints, specially designed to allow the maximum lateral movement without leakage. Two types of pipe joint were used—one for the solid ground in the upper districts, where earthquake vibration produces the minimum effect, the other for the filled-in lower portions of the city, where the movement would be a maximum. For the first locations, bell and spigot pipe was used, while in the districts more seriously affected by earthquake, a double-spigot sleeve joint, which allows twice as much lateral motion as a bell-and-spigot connection, was adopted. Both types are shown in Fig. 3.

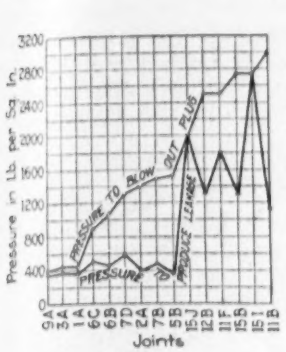
Before determining a type of bell best adapted to withstand lateral movement without destroying the permanency of the joint, an elaborate series of tests were conducted under the direction of T. Ransom, the consulting mechanical engineer of this bureau, at the plant of the Union Iron Works, of San Francisco. Cross-sections of the various types tested are shown in Fig. 4-A.

For all tests, a special test bell and plug shown in the same diagram were used, and regrooved as required. The plug was fitted into the bell, 1 in. of yarn calked into the joint, and the remaining 3½ in. poured full of lead, which was thoroughly hand calked with three sets of tools of which the faces were 1 in. long and $\frac{3}{16}$ in., $\frac{5}{16}$ in. and $\frac{7}{16}$ in. wide, respectively. Water was introduced into the bell through a ⅜-in. tap and pressure applied by means of a force pump. Measurements of the leakage and movement of the plug were then accurately made. The final pressures developed before plugs of the various types were forced entirely out of the bell and also the pressure necessary to produce leakage are shown in Fig. 4-B. In Fig. 4-C are indicated the distances that plugs were forced out of bells. The relation between bending

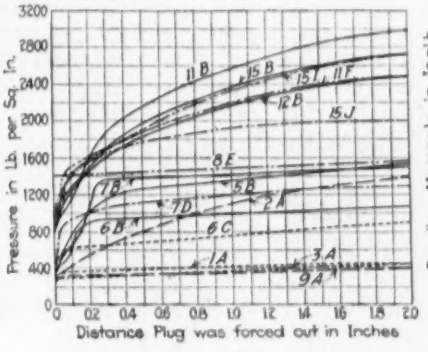
movements and corresponding distortion at the end of a 12-ft. length of pipe are given in Fig. 4-D and the relation of leakage to pressure is shown in Fig. 4-E.

On the basis of the above tests, the joints shown in Fig. 3 were adopted, as this type allowed the greatest lateral distortion with the least leakage.

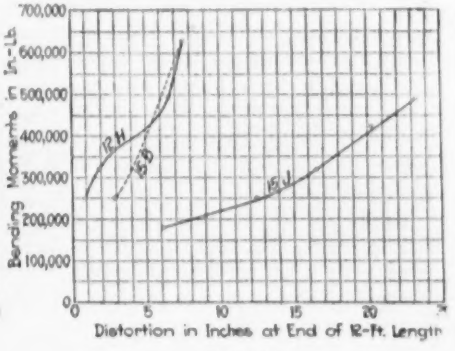
special design of bell already noted, it closely conforms to the specifications of the New England Water-Works Association. It was tested at the factories by R. W. Hunt & Co. On its arrival at San Francisco each piece was subjected to a pressure of twice the intensity to which it would be stressed in the system, and every defective pipe



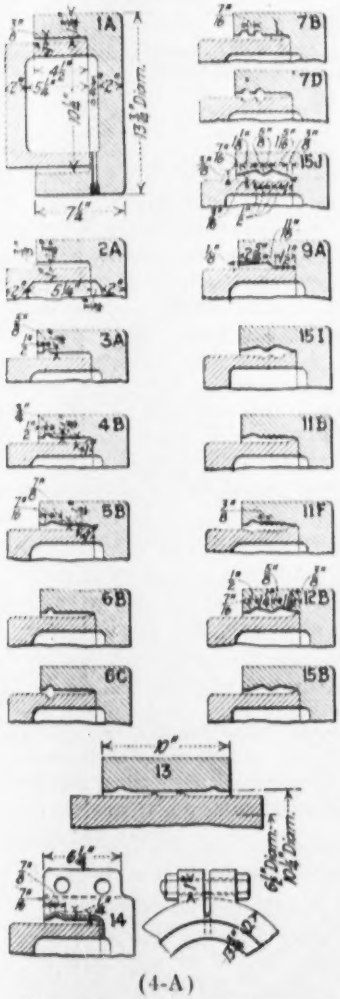
(4-B)



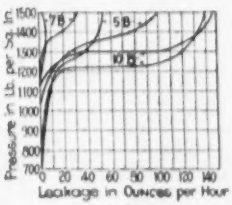
(4-C)



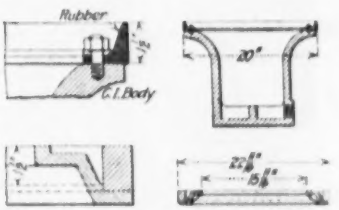
(4-D)



(4-A)



(4-E)



(4-F)

Fig. 4A—Types of Bell Tested.

Fig. 4B—Unit Pressure on each Joint at Failure.

Fig. 4C—Outward Movement of Plug under Pressure.

Fig. 4D—Relation of Deflection of Joint to Bending Moment.

Fig. 4E—Joint Leakage in Tests.

Fig. 4F—Device for Testing Pipe for Leakage after Laying.

FIGS. 4-A TO 4-E. EFFICIENCY TESTS ON PIPE BELLS

discovered at the time was rejected. The remainder was stored in the municipal pipe yard, and supplied to the various contractors as needed.

Pipe laying was performed under seven different contracts. The city supplied pipe, hydrants, valves and all appurtenances. Each contract was in charge of an assistant engineer assisted by as many inspectors as were necessary to insure the fulfillment of the specifications.

For lowering large sized pipe into the trench, a steam hoist was first used experimentally. Due to the existence of numerous small service pipes across the line of the trench and because the hoist proved cumbersome on heavy grades and blocked traffic on crowded streets, this method was not efficient. A pipe tripod was tried and found unsatisfactory, so a framed horse of the dimensions shown in Fig. 5 equipped with a triplex hoist-block was finally used with excellent results. On steep grades it was frequently necessary to point some bells down hill. Such joints were made with lead wool and when properly calked gave entire satisfaction. After several blocks of pipe were laid and calked, the trench between the joints was backfilled, and the bells left exposed. The pipe was then tested, the test pressure varying with the class of pipe, as follows:

Class of Pipe	Used for Head of	Test Pressure, Lb. per Sq. In.
G & H	600 to 760 ft.	450
F	500 to 600 ft.	400
E	400 to 500 ft.	350
D	300 to 400 ft.	300
C	200 to 300 ft.	250
B	100 to 200 ft.	200
A	0 to 100 ft.	150

Pipe was supplied by the United Cast Iron Pipe Co. at a price of $19.90 per ton for bell-and-spigot, and $20.50 per ton for double-spigot pipe, f.o.b. cars at Bessemer and Anniston, Ala. With the exception of the

Pipe to be tested was filled with water and the specified pressure applied by means of a double-cylinder force pump. This pressure was maintained for 20 minutes. If during that period the additional water introduced to

keep the pressure constant exceeded 0.0055 gal. per lineal foot of pipe joint under test, the contractor was forced to recalk all joints that gave any evidence of leakage.

The first tests were performed between adjacent valves. For large mains a pressure of 450 lb. per sq.in. would invariably move the valves outward along the adjacent pipe. In soft ground it was exceedingly expensive to provide a backing sufficiently solid to hold the valve absolutely rigid in place. It was highly essential that there should not be the slightest motion of the valve outward along the spigot of the pipe inserted into its bell, for if motion occurred, then when pressure was put on the opposite side of the valve it was forced back, with a consequent serious leak.

To obviate this the special type of test plug shown in Fig. 4-F was designed by this office. The plug was provided with a rubber-cup gasket, as shown, and a tap through which the pipe under test was filled with water. The plug was braced in place against a suitable timber backing. It was not necessary that the backing be absolutely rigid for the only motion under pressure would be a slipping of the plug outward, which caused no inconvenience; for even when the plug slipped several inches it held pressure without leakage. The same gasket could be used for a number of tests, and when worn or injured, could be removed and a new one substituted.

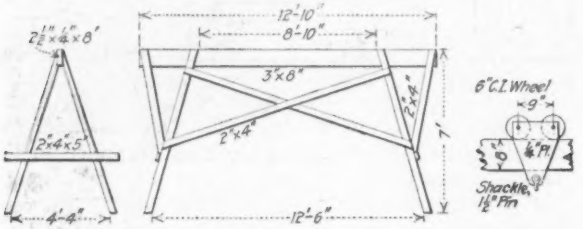


FIG. 5. DEVICE FOR LOWERING PIPE INTO TRENCH

A notable feature of the pipe-distribution system is its division into independent units by a series of gate valves. These units are generally one block in length with a valve at both ends. The pipe system is laid out as a gridiron so that in case of a break any block or any number of blocks can be cut out by closing several valves and the remainder left in perfect working condition. An additional precaution was taken in the lower filled-in areas, where the effect of earthquake vibration is much more pronounced. The gridiron pipe layout that supplies this area is connected to the remainder of the system at numerous locations, but at all except one of these connecting points, the valves are kept closed. Thus, in the event of a serious fire, the chief of the fire department, by ordering these valves opened, will have available as much water as in any other part of the system; but in the event of an earthquake destroying any of the pipes in the filled-in district, the entire area can be shut off from connection with the rest of the system by closing only one valve.

In all 889 hydrants, each having three 3½-in. outlets, are connected to the distribution mains by 8-in. branch pipes. The hydrants are all fitted with shut-off king valves below the surface of the street and with auxiliary nozzle valves on each outlet. To provide for repairs on hydrants, an additional valve is located on the 8-in. branch lines leading to them. The hydrants were manufactured by the Union Iron Works Co., of San Francisco, from designs similar to those of the hydrants in use in New York City.

The excellence of the workmanship on San Francisco's high-pressure pipe system is illustrated by a comparison with New York's fire system. The latter comprises 105 miles of mains, which are maintained under a pressure of 30 lb. per sq.in., and from which the leakage is approximately 850 gal. per minute or 1,200,000 per day. The San Francisco system contains 71.81 miles in which an average pressure of 200 lb. per sq.in. is maintained and the leakage is only 152,000 gal. per day, equivalent to a

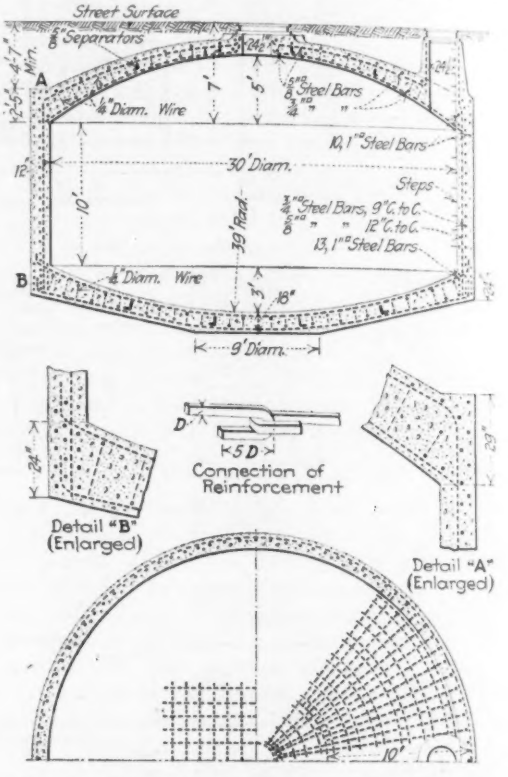


FIG. 6. REINFORCED-CONCRETE FIRE CISTERN

leakage of only 59,000 gal. per day under a pressure of 30 lb. per sq.in. Since the length of pipe in the San Francisco system is only 71.81 miles, and that in the New York system 105 miles, this 59,000 gal. per day in 71.81 miles of pipe is equivalent to 86,000 gal. per day in 105 miles of pipe, or the leakage per mile in San Francisco's system is only 7.2% of the leakage in the New York system.

CISTERNS

Beside the pipe distribution system, the auxiliary water supply includes 135 underground cisterns, from which water can be pumped in case high-pressure mains are ever disabled. Numerous brick cisterns existed at the time of the 1906 disaster, but they had not been maintained and their location was unknown to the fire department. Had they been in condition and full of water, the fire could have been confined to a very much smaller area. Fifty of the old cisterns have been repaired since 1906 and are now in first-class condition, and 85 new cisterns of reinforced concrete have been constructed. These are built beneath the surface at street crossings, and their

position is indicated by a distinctive type of pavement around their perimeter. The top and bottom are diverging domes, as shown on Fig. 6. The average diameter is 30 ft. and the average capacity 75,000 gal. All are very heavily reinforced and designed to stand vibration. For this reason no pipes for filling or emptying are rigidly connected with the cisterns, as they might exert a disrupting force.

All records of underground structures were destroyed in 1906. It was therefore necessary, before locating a cistern on any corner, to make a complete underground survey of the immediate locality. This was done by digging exploration trenches and platting the information obtained.

That the cisterns can stand vibration without injury was shown conclusively. During the construction of one of them a heavy rainstorm occurred and floated it about 6 ft. above its foundation. After the storm the water was drained away and the structure settled back on its foundation. A careful investigation failed to reveal the slightest injury, and when the cistern was filled with water no leakage could be detected.

At high-pressure hydrants no fire engines are required. The engines are retained, however, for use in districts not covered by the high-pressure lines, and also for pumping from cisterns.

Fireboats

Additional protection to the water front and shipping interests is afforded by two fireboats, which are constructed with steel hull and deck house. Their dimensions are: Length, 120 ft.; beam, 26 ft.; draft, 11 ft.

Each boat is fitted with two Babcock & Wilcox water-tube boilers, which have an aggregate heating surface of 5400 sq.ft. The propelling engines, of which there are two for each boat, are 13x28x20 in., of the compound-condensing type. The speed of each boat is 12 knots per hour. Each is equipped with two Curtis steam turbines and two-stage turbine pumps, which have a nominal capacity of 9000 gal. per minute against a pressure of 150 lb. per sq.in. The fire-fighting equipment consists of three 3-in. monitor nozzles, two 2-in. monitor nozzles, and twenty 3½-in. hose connections.

When tested by the committee on fire protection of the National Board of Fire Underwriters in 1910, the actual capacity of one of these boats was found to be 9870 gal. per minute against a pressure of 150 lb. per sq.in., and 10,310 gal. per minute against a pressure of 139 lb. per sq.in.

Pipes have been run out on the dock and manifold connections attached so that in case of necessity the two fireboats can pump into the mains of the high-pressure system, and supply 10,000 gal. per minute at a pressure of 300 lb. per sq.in.

Fire-Alarm System

In connection with the auxiliary water-supply, a new fire-alarm system has been installed. Wherever possible, cables were laid in vacant existing ducts. On many streets, however, it was necessary for the city to lay its own conduits. These were installed in the same trenches and at the same time as the high-pressure pipes.

Ducts were of creosoted wood, 4½x4½ in. square, with 1½-in. creosoted cover planks. Both single- and multiple-duct conduits were laid, depending on the number of cables to be provided for. In each block they terminated at valve vaults or vaults of either of the operating telephone companies. In laying the ducts, before driving the tenon into the mortise, it was thoroughly painted with asphalt and then driven completely home, in order to secure a water-tight joint. Multiple ducts were laid so as to break joints both horizontally and vertically, and collars of 1½x4½-in. creosoted plank, spaced at 6-in. intervals, hold them together. Upon the completion of each block, a mandrel 3 ft. in length and ¼ in. smaller

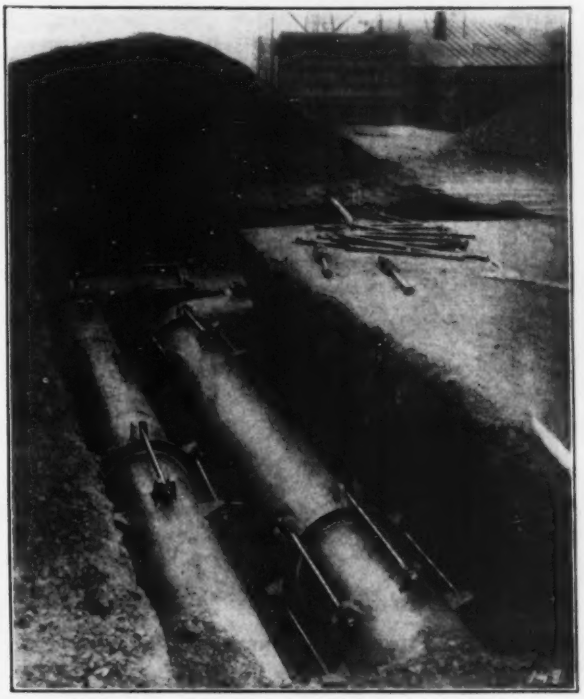


Fig. 7. Outlet Pipes from Twin Peaks Reservoir

in diameter than the normal size of the duct, was drawn from manhole to manhole. Ducts through which this could not be drawn were taken up and relaid by the contractor at his own expense.

The central fire-alarm station is situated in Jefferson Square, at the intersection of Turk and Octavia St.

Especial care was taken to provide a location for this building which would be as nearly as possible free from fire hazard. This was the reason for selecting its site in the center of a public park. All material incorporated in the station is absolutely fireproof, no wood whatever having been used in its construction. Further, no gas was brought into any portion of the structure where an explosion could cause damage to the fire-alarm equipment. Hot-water heat is provided by a gas heater, but this appliance, together with a gasoline-engine driven generator, is separated from the rest of the building by a 10-in. reinforced-concrete wall.

All alarms from street boxes are received at the central station on telegraph sounders and registers. The street boxes are arranged to sound in their number four times. After receipt of the number twice, the operator attending the box circuit calls the number of the box to the operator, whose duty it is to send the alarm to the engine house. He in turn transmits the number four times; twice over a tapper circuit and twice over a gong circuit. The tap-

per circuit is arranged for quick action and sends a practically silent alarm, which is received at the engine houses on a small bell. The gong circuit confirms the information transmitted over the tapper wire. This arrangement of operation is known as the manual system, no provision being made for the transmission of alarms directly from fire-alarm boxes to engine houses.

The central-station switchboard comprises 41 panels. All are not equipped at the present time as provision has been made for growth. The switchboard proper is 102

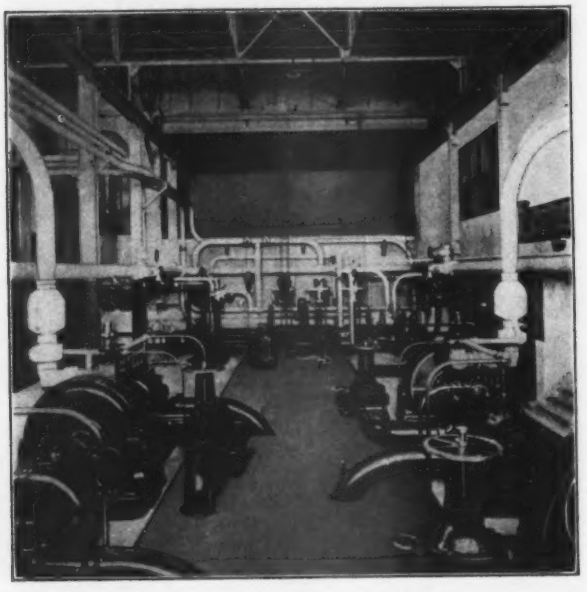


FIG. 8. PUMPS IN TOWNSEND ST. STATION

ft. in length, and when fully equipped will handle 88 box or signal circuits, 16 tapper, 16 alarm and 16 joker circuits, together with hospital panel for 12 signal circuits, 2 tapper circuits, 2 alarm circuits and 2 joker circuits. The hospital service provides for the transfer of any circuit from its regular position in the board to a separate panel, where it will be supplied with the necessary current from a motor-generator set, one such machine being supplied for each hospital circuit. In this way, grounded or crossed lines can be entirely isolated and connected to a panel provided with special equipment for the treatment and operation of crippled lines.

The source of power is a storage battery of 280-ampere-hour capacity. From this battery are driven dynamotors through which power is furnished to the various circuits. Current for four lines is taken from each dynamotor. This arrangement was made in order to insulate the lines from each other and the battery from the ground.

Particular care has been taken in laying out the device for charging the storage battery. Provision has been made to charge it from the direct-current mains or the alternating-current mains of the two different companies. Further safety has been secured by the installation of a gasoline-engine driven generator, which, in emergency cases, can be used to supply current for the battery and lights for the building.

REPAIR OF TWIN PEAKS RESERVOIR

As previously noted, when first completed and filled with water the leakage from Twin Peaks reservoir was excessive. From a single compartment there was a waste of more than 2,000,000 gal. daily. During the year 1913 this leakage was entirely eliminated. The method followed was first to remove the defective asphalt filler, which was done with a plowshare mounted on wheels and moved along the joint by means of a windlass. The oakum originally placed in the joints was next driven below the bottom of the concrete and left embedded in the loose rock surrounding the underdrain. The joints were then shaped with hand chisels and a cavity in the underlying loose rock excavated along the entire length. The sides and bottom of the joints were then coated with paint and when this had dried were filled with a mixture composed of asphalt and infusorial earth.

For joints in the bottom of the reservoir the consistency of the mixture was 95% D-grade asphalt with 5% infusorial earth, poured at a temperature between 300° and 400° F. Into the slope seams a stiffer mixture, to avoid flowing, of 82½% asphalt and 17½% infusorial earth was poured at a temperature ranging from 375° to 400° F. On top of this a 6-in. strip of felt was placed and ironed down and later mopped with asphalt. The whole surface of the reservoir was finally coated with asphalt. To secure perfect adhesion between the asphalt and joints was extremely difficult and in several instances had to be repeated before the leakage was successfully prevented. The reservoir is now as impervious to leakage as it is possible for a concrete reservoir to be made.

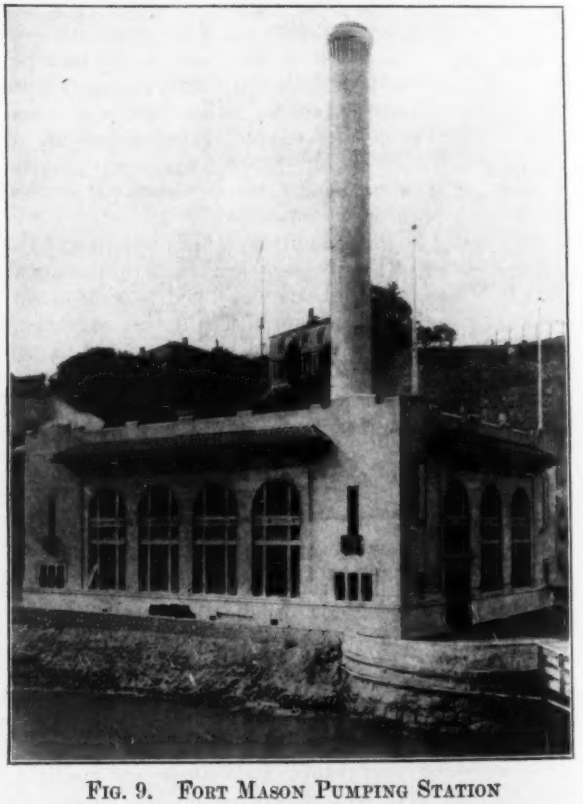


FIG. 9. FORT MASON PUMPING STATION

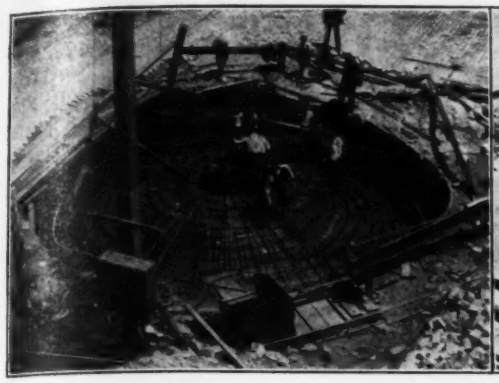


FIG. 10. PLACING REINFORCEMENT IN DOME OF CISTERN

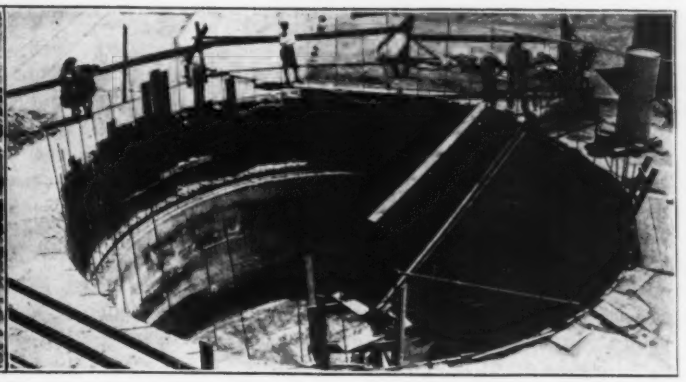


FIG. 11. FIRE CISTERN DURING CONSTRUCTION

The following is a cost summary for the high-pressure system:

Purchase of lands	$110,967
Reservoirs	680,597
Fireboats	369,208
Pump stations	837,693
Pipe yard grading and equipment	23,856
Purchase of 90 miles pipe and valves	2,425,365
Unloading and storing pipe and valves	65,307
Laying 72 miles of mains	972,102
Engineering and overhead	232,964
Total	$5,718,059

COST OF CONSTRUCTION OF MAINS

Figures include only the wages of foremen, mechanics and laborers immediately engaged upon the work. Add 10% for general superintendent, timekeepers, watchmen, service wagon, and depreciation and repair of tools. The total cost of construction to the contractor will be obtained by adding the cost of all materials used, and the overhead expense, including office expense, liability insurance, etc.

COST OF LABOR, AS ESTIMATED BY ENGINEERS IN CHARGE OF CONSTRUCTION

1. TRENCH WORK:

Removing pavements having concrete base, $0.06 per sq.ft.

Removing pavements without concrete base: not counted separately, as cost was found to be practically equal to that of an equal volume of ordinary digging.

Excavating and backfilling trenches and removing surplus excavated material.

Nature of Ground	Labor Cost per Cu.Yd. Congested District	Average Conditions
Sand, about one-half lagged	$1.10	$0.95
Sandy clay	1.25	1.10
Hard clay	1.40	1.25
Soft rock (shale, red chert)	.....	1.40
Hard rock (gadding, some blasting)	$4.00	$6.00

2. LAYING PIPE (Not including setting valves and hydrants):

Kind and Size of Pipe	Cost of Labor, per Foot: Hauling	Laying	Calking	Testing	Total
Congested district:					
Bell and spigot pipe: 8-in. (hydrant connection; all joints bolted)	$0.05	$0.17	$0.25	$0.02	$0.49
10-in.	0.06	0.16	0.11	0.02	0.35
12-in.	0.07	0.17	0.11	0.02	0.37
14-in.	0.09	0.26	0.12	0.02	0.49
16-in.	0.11	0.19	0.16	0.02	0.48
18-in.	0.12	0.25	0.14	0.02	0.53
Spigot pipe, sleeve joints:					
10-in.	0.07	0.13	0.14	0.02	0.36
12-in.	0.08	0.13	0.17	0.02	0.40
14-in.	0.10	0.13	0.20	0.02	0.45
16-in.	0.12	0.23	0.21	0.02	0.58
18-in.	0.14	0.15	0.24	0.02	0.55
Average Conditions:					
Bell and spigot pipe: 8-in. (hydrant connections; all joints bolted)	$0.03	$0.29	$0.12	$0.01	$0.45
12-in.	0.05	0.06	0.07	0.01	0.19
14-in.	0.07	0.09	0.08	0.02	0.26
16-in.	0.08	0.10	0.12	0.02	0.32
18-in.	0.10	0.19	0.14	0.04	0.47
Spigot pipe, sleeve joints:					
12-in.	0.06	0.11	0.14	0.02	0.33
16-in.	0.09	0.06	0.15	0.03	0.33

Note: Cost of calking, per joint, was as follows:

	Congested District	Average Conditions
8-in. joints	$0.90	$0.90
10-in. joints	0.85	.....
12-in. joints	1.00	0.78
14-in. in	1.10	0.90
16-in. joints	1.25	1.23
18-in. joints	1.40	1.44

3. SETTING GATE VALVES AND HYDRANTS:

8 in. gate valves, each	$4.50
10-in. gate valves, each	4.50
12-in. gate valves, each	6.00
14-in. gate valves, each	7.50
16-in. gate valves, each	10.00
Hydrants, each	5.00

4. MISCELLANEOUS ITEMS:

Setting manhole castings	$7.00 per ton
Bolting joints of pipe lines	$24.00 per ton
Concrete valve vaults—labor only	$9.60 per cu.yd.
Setting reinforcing steel in valve vaults	$14.00 per ton
Laying creosoted wooden telephone duct	$0.036 per duct-foot

5. WAGE SCHEDULE, per day of eight hours:

Superintendent	$ 6.00 up
Foreman	$ 4.00 to $5.00
Straw boss	$ 3.50 to $4.00
Calker and yarner	$ 4.00
Leadman	$ 3.00 to $3.50
Laborer, watchman	$ 3.00
Team and driver, 4-horse	$10.00
Team and driver, 2-horse	$ 6.00
Team and driver, 1-horse	$ 4.50

Costs of San Francisco Sewers

Sewer construction work has been financed by two bond issues. The first, in the sum of $7,248,000, bearing interest at the rate of 3½%, was voted in 1903. Owing to the low rate of interest only $1,449,600 could be realized from the sale of these bonds so in 1908 bonds worth $5,254,800 were canceled, leaving unsold and uncanceled bonds having a value of $43,600.

In the same year a new issue to the amount of $4,000,000 was authorized on which interest at the rate of 5% was paid. Practically this entire issue has been disposed of, at a premium amounting to over $300,000. To complete the system $4,000,000 additional will be required.

Accurate cost data on all construction work were kept by the Bureau of Engineering.

The following is a typical labor-cost summary for an 8-ft. circular reinforced-concrete sewer built between electric-car tracks in a street within the commercial district (Howard St. from Second St. to Fourth St., a distance of 1650 ft.):

UNIT COSTS OF 8-FT. SEWER

Excavation	$7.86 per lin.ft.	$0.618 per cu.yd.
Lagging	6.450 per lin.ft.	0.106 per sq.ft.
Forms	1.765 per lin.ft.	0.070 per sq.ft.
Steel	1.480 per lin.ft.	0.028 per lb.
Concrete	6.915 per lin.ft.	5.310 per cu.yd.
Brick lining	0.691 per lin.ft.	0.046 per brick
Finishing	0.348 per lin.ft.	0.014 per sq.ft.
Backfill	2.020 per lin.ft.	0.202 per cu.ft.
Miscellaneous	0.567 per lin.ft.	
Total	$28.096 per lin.ft.	

The pavement consisted of basalt blocks on sand. During construction the street was left open to vehicular traffic. Ordinary labor was at the rate of $0.37½ per hr. and superintendence at $0.50 and $0.625 per hr.

A description of the sewerage system of the city appears on p. 305.

San Francisco's Future Water-Supply: Hetch Hetchy Project

As early as 1865 San Francisco realized the necessity of an extensive program of water-supply development. Subsequently the several city administrations considered various phases of the matter and it was soon evident that the local peninsula sources would be inadequate for the ultimate needs of San Francisco.

The water-supply at and near San Francisco Bay is quite limited. The local sources are drawn from the Coast Range of mountains, which in general is less than 3000 ft. in elevation and in the region of San Francisco Bay roughly parallels the Pacific Coast.

The rainfall of the Coast Range is quite meager and is confined to the season from December to March, inclusive, the remaining months of the year being practically a period of drought. There are also seasons when even in the rainy months the rainfall is small, and to safeguard the water-supply against these annual periods of drought and further provide against the occasional seasons of very low rainfall and other uncertainties, enormous storage must be provided.

East of the Coast Range lies the San Joaquin Valley, about 45 mi. in width, which separates this range from the Sierra Nevada Mountains. These form an extensive mountain chain, constituting a considerable portion of the eastern boundary of California. Here the rainfall is quite prolific, and the runoff of the many streams draining the western slope of this range is considerable. It is to this locality that San Francisco has finally turned for future protection to augment its inadequate local sources of water-supply.

The first extensive study of the sources of water-supply for San Francisco was made in 1900, when the city appropriated $50,000 for this purpose. On the basis of the studies then made of twelve separate projects, the city selected the Tuolumne River as the most feasible and most economical source.

The Source of Supply

The drainage basin from which San Francisco will derive its water-supply and power lies near the summit of the Sierra Nevada Mountains, 150 mi. to the east of the city. It comprises 420,000 acres of the watershed of the Tuolumne River in and above Hetch Hetchy Valley, the territory tributary to Lake Eleanor, and the area which drains into Cherry Creek. These watersheds are practically entirely in a region of granite rocks and include a belt of country between altitudes of 3500 and 2000 ft. The upper region of the Tuolumne shed consists of a series of more or less broad, flat valleys, resulting from glacial scour in past geological history. San Francisco proposes to construct and maintain broad, well surfaced roads to its holdings in the Sierras, so that the scenic trip there may be made in comfort by automobiles.

Fig. 1. Lake Eleanor Reservoir Site, Future Water-Supply of San Francisco

It must be understood that the drainage area composing San Francisco's Tuolumne River water-supply lies almost wholly within the Yosemite National Park, and the Sierra Forest Reservation. Before any development work could be undertaken it was necessary that the city get proper authorization from the Federal Government. This authorization was obtained in May, 1908, being a permit issued by the Hon. James R. Garfield, Secretary of the Interior.

San Francisco's proposed scheme of development of

this source is to create storage in the Hetch Hetchy Valley and at Lake Eleanor and elsewhere by means of dams. (Fig. 1 is a view of the Lake Eleanor and Fig. 2 of the Hetch Hetchy Reservoir site.) Under the provisions of the Garfield permit, issued in May, 1908, the city was required first to fully develop the Lake Eleanor and Cherry Creek sources before commencing the construction of the Hetch Hetchy Dam. It was further provided in the Garfield permit that the project be submitted to the citizens of San Francisco for ratification, and that the city should buy up all lands held by private owners around Hetch Hetchy, Lake Eleanor and elsewhere which would be necessary for its water-supply. This matter was voted upon in December, 1909. The proposition submitted to the voters provided for the acceptance of the terms of the Garfield permit and for a bond issue of $600,000. It was carried by a vote of more than five to one.

The various private land holdings and water-rights were subsequently bought. In January, 1910, the Secretary of the Interior, R. A. Ballinger, suggested that the city show its good faith by a bond issue sufficient for the initial development of the Tuolumne sources. Several propositions were submitted to the voters, but the one finally adopted was for a bond issue of $45,000,000 for the construction of the city's mountain water-supply. At this election, out of over 30,000 votes cast only 1200 were recorded in opposition.

In the purchase of lands and water-rights the city had spent over $1,500,000, had complied with all the provisions of the Garfield permit, and had further shown its good faith by an overwhelming vote in providing sufficient funds for immediate development of its water-supply. In 1909, however, Secretary Ballinger practically revoked the Garfield permit by commanding San Francisco to show cause why certain portions of this permit, including the right to use Hetch Hetchy Valley for a reservoir, should not be withdrawn by the Government. The entire question hinged upon whether or not the city actually needed the Hetch Hetchy Valley for reservoir purposes. After several hearings, at the suggestion of President Taft, the entire matter was submitted to a Board of United States Army Engineers, composed of Colonels Biddle, Cosby and Taylor. Under the direction of this Board the broad question of the proper and most economical source of water-supply for San Francisco was reopened, and all of the various sources, local and elsewhere, were again investigated. In this investigation, San Francisco alone spent nearly $300,000 in compiling engineering data. Owing to the pressing need of other cities bordering on San Francisco Bay, whose necessities were common with those of San Francisco, this city undertook the study of the requirements of the municipalities of the entire San Francisco Bay region. On the basis of these studies, it was found that after fully developing all the local sources, there would be needed an additional supply of about 400 million gallons daily. It was necessary, then, that the Sierra sources, or the sources finally selected, should have a safe, dependable yield of over that amount. After a most thorough investigation of various Sierra Nevada sources, filtration schemes on the San Joaquin and Sacramento rivers, together with several Coast Range schemes lying considerably to the north of San Francisco, the city engineering staff again came to the conclusion that the most feasible, economical and adequate source of water-supply was the one previously selected, namely, the Tuolumne River.

In its report to the Secretary of the Interior, the Board of Army Engineers fully sustained San Francisco's contentions as to the adequacy and desirability of the Tuolumne River sources, and the desirability at the present time of securing future sources. At the suggestion of the Secretary of the Interior, who declined to assume responsibility, the matter was submitted to Congress, and what is now known as the "Raker Bill" was approved by that body on Dec. 7 and was signed by President Wilson on Dec. 19, 1913.

In the studies of the various sources of water-supply, San Francisco approached the problem with a very broad view. The large commercial interests of the great San Joaquin and Sacramento Valleys (flanking the Sierra Nevadas on the west) were duly considered. In these studies, consideration was given to the irrigation needs of the adjacent irrigable lands, and only such waters as remained after fully allowing for just and reasonable needs of the developed districts were deemed available for diversion and the use of San Francisco and the Bay Cities. On the waters of the Tuolumne River, the Modesto and Turlock Irrigation districts have prior rights to over 2000 sec.-ft. of the natural flow of the stream. These districts comprise about 257,000 acres of San Joaquin Valley lands, and they were properly concerned in the safeguarding of their valley rights.

San Francisco made a very thorough and careful investigation of their needs and has always been liberally disposed wherever irrigation rights were concerned.

Order of Development

Hetch Hetchy Dam—The first permanent construction to be undertaken in this project, aside from the necessary roads, etc., will be the Hetch Hetchy Dam. This will be located on the Tuolumne River at a narrow gorge at the outlet of Hetch Hetchy Valley. The structure will be of the heavy-masonry type, 300 ft. high and 800 ft. long, and will serve to impound 112 billion gallons of water. With this storage, even under the most severe conditions of draft by San Francisco, the floor of the Hetch Hetchy Valley will always be covered by a broad long lake, around which there will be a scenic road built by the city.

While the Hetch Hetchy Dam is in progress, work will also be started on the conduit at what is known as the "Early Intake," and on the main aqueduct and permanent power house at Moccasin Creek.

Early Intake—It is proposed in the future to lead the water from Hetch Hetchy Dam to San Francisco entirely in closed conduits, but for the present the first 12 mi. of this conduit down to the mouth of Cherry Creek will not be built. The water will be allowed to flow down the natural channel of the Tuolumne River to the Early Intake. At this point there will be built a temporary overflow dam about 45 ft. high and 500 ft. long. This will intercept the water released from the Hetch Hetchy Reservoir and divert it into a pressure tunnel 10½ ft. in diameter. This tunnel, which will be a part of the permanent main aqueduct, will pass through the solid granite mountains for a distance of 20 mi. to a forebay reservoir of 2000 acre-ft. capacity, thence to the Moccasin Creek power station. The tunnel will be lined with concrete, thus excluding any underground seepage water

from the mountains, and at the same time this smooth surface will increase the carrying capacity. This tunnel will be capable of delivering over 400 million gallons daily.

Power House at Moccasin Creek and Cherry Mouth—There is only one power drop in the aqueduct line first to be constructed. The power-house site for this is located beside the main highway at Moccasin Creek and about 141 mi. distance from the city hall in San Francisco. At this power house there will be a net drop of 1250 ft., which will make available for use at San Francisco about 50,000 hp., as a first installation of construction.

units, with reservoirs at higher levels, will be added to the system. The water from these two sources will be delivered to the Hetch Hetchy Reservoir by means of concrete-lined tunnels about 8 ft. in diameter.

Conduit to San Francisco—As previously stated, in the first installation the water from Hetch Hetchy Reservoir will flow down the natural bed to the Tuolumne River for a distance of 12 mi. to the Early Intake; thence through a 10½-ft. pressure tunnel to the Moccasin Creek power house 20 mi. below. The aqueduct from this point will consist of a concrete-lined tunnel about 12 ft. in diameter, for a distance of 16 mi. to the easterly edge of the San Joaquin Valley. This valley, which is 45

Fig. 2. Site of the Hetch Hetchy Reservoir for the Future Water-Supply of San Francisco

Whenever the upstream twelve miles of aqueduct between the Early Intake and the Hetch Hetchy Dam is built, another power drop will become available just above the Early Intake. At this power house there will be a net drop of 1325 ft., which will deliver to the city about 60,000 hp. continuously.

It may be of interest to note that from an energy standpoint, one mechanical horsepower is the equivalent of 5½ tons of coal. The great economic value to the nation of the future development of 200,000 hp. from this municipal source, without the consumption of coal or oil, can easily be appreciated.

At some future date when the needs of the Bay District shall demand it, the Cherry Creek and Eleanor mi. in width, will be crossed by means of a pipe conduit. The size of the pipe, and whether one large or two small ones will be used, are economic and engineering problems which present municipal needs have not definitely decided. The original plans call for steel pipe 7½ ft. in diameter, lined on the inside with 1½ in. of cement mortar; one pipe to be laid for the first installation, and later a second one parallel to it. More study will be necessary to decide on the construction features of this portion of the route.

The San Joaquin River being a navigable stream, will have to be crossed by a submerged siphon about 600 ft. long.

At the westerly edge of the San Joaquin Valley the

pipe lines will connect with another length of conduit through the Coast Range of mountains. From this point the aqueduct proceeds in a westerly direction, mostly in the form of a concrete-lined tunnel, 12 ft. in diameter, a distance of 32 mi., to the proposed Irvington Gate House. Then the conduit will be carried westerly in the form of a pipe (possibly of the same character as the steel pipe described above) for a distance of 19 mi. This pipe will be submerged in crossing the head of San Francisco Bay at Dumbarton Narrows. Special construction will be required to carry it over the marsh lands bordering the bay. The conduit will be carried around the head of the bay on dry-ground if this is found desirable and economical after further detailed study. After crossing the bay the aqueduct will rise to a point of suitable elevation in San Mateo County, from which the water can flow by gravity either into the great storage reservoir of the Spring Valley Water Co., at Crystal Springs, or can feed branch lines to outlying districts, and a main aqueduct line leading directly to San Francisco.

The valves and connections all along the route will be arranged so that the water can ultimately be delivered either directly from the Hetch Hetchy Reservoir into the municipal distributing pipes without passing through any reservoir, or can be diverted into any of the several storage reservoirs around the Bay.

The entire length of the aqueduct from the Hetch Hetchy Dam to the city hall in San Francisco will be about 170 mi.

ESTIMATE OF COST—The first unit of the Hetch Hetchy Project will deliver at Irvington Gate House a maximum of 240 million gallons daily, and during the periods of extreme drought a minimum of 160 million gallons daily. All tunnels will be built to their full capacity of over 400 million gallons daily in the first installation.

The cost of this first unit will be above $37,000,000. The final completion of the entire project for delivering 400 million gallons daily to the San Francisco Bay District will cost about $77,000,000.

San Francisco at present uses about 41 million gallons of water per day from the Spring Valley Water Co., and over 8½ million gallons from local underground sources, making a total daily usage of practically 50 million gallons.

Calaveras Dam, now being constructed by the Spring Valley Water Co., will add about 20 million gallons per day to the present supply. This will be sufficient to meet the increased demands for a few years only—barely long enough to permit of the first delivery of water from Hetch Hetchy.

Due to the completion of the Panama Canal, and the exceptional agricultural opportunities in the Sacramento and San Joaquin Valley, the growth of the communities around San Francisco Bay will be greatly accelerated in the next ten years, and the preservation of the prosperity of the cities demands that an adequate water-supply be made available at the earliest possible date.

For transporting material to the proposed Hetch Hetchy Dam and its vicinity, a road is being constructed from Hog Ranch to the dam site, a distance of 9.09 mi. The roadbed will be 22 ft. wide, with a maximum grade of 4%. The contract for the construction of this road was awarded on July 8, 1914, to the Utah Construction Co., for the estimated price of $151,500. A contract for laying a temporary construction railroad over this grade will probably be let in 1915. About 59 mi. of additional roadbed will be graded in 1915 and tracks laid, so that materials for construction of the dam and aqueduct can be economically transported.

Garbage and Refuse Disposal and Experiences with Incineration at San Francisco

San Francisco, like many other large cities, has had considerable difficulty in disposing of its garbage and other refuse in a manner that is both inoffensive and economical. At the present time ashes, hotel refuse and rubbish are collected by licensed scavenger wagons. Each scavenger makes his own terms with the householder and pays to the Sanitary Reduction Works, which operates the only incinerator within the city limits, the sum of 60c. per ton for disposing of the material he hauls.

Much of the garbage from hotels and restaurants is purchased by hog and chicken ranchers and hauled to San Mateo County. A large precentage of the malt refuse from the manufacture of beer is likewise disposed of. Stable manure is hauled by vegetable growers to their gardens on the outskirts of the city and used as fertilizer. Most of the manure from private stables is delivered to the reduction works and incinerated. Dead animals are disposed of by a subsidiary company which operates in conjunction with the Sanitary Reduction Works, and reduces the carcasses to saleable materials, such as grease, bones and oil. Butcher-shop refuse is for the most part treated for the recovery of grease and tankage.

The Sanitary Reduction Works, which operates under a franchise dated Feb. 26, 1896, issued to F. E. Sharon, his associates and assigns, for a term of 50 years, had the exclusive right to destroy by cremation all house refuse, offal, garbage, rubbish, dirt, cinders, bones, and other like materials, putrid vegetable matter, fish and food condemned as unfit for human food. The franchise was granted for the sum of $2510 and the further payment of 2% of the gross receipts derived for a term of 15 years after the date of the franchise, and 5% for the remaining term of 35 years. In order to operate its own municipal incinerator it was therefore necessary for the city to purchase the plant of the Sanitary Reduction Works, which it proceeded to do.

An incinerator formerly owned by this company is located on the block bounded by Rhode Island, Alameda, DeHaro, and 15th streets. It was completed and placed in operation in 1897. The equipment consisted of two furnace units of the Charles Thackaray type arranged in four batteries of eight furnaces each. The batteries may be operated independently.

The dimensions of each furnace are 8x12 ft., and all are fed from charging platforms and provided with inclined grates. Smoke and hot gases from the grates discharge into a metal flue which conveys them to a brick stack 250 ft. in height. This provides the natural draft under which the incinerator is operated.

Garbage is delivered into wooden bins, whence it is raked and shoveled by hand to a hopper at the rear of each furnace; thence it is emptied on to the grate by men on the firing floor who use long rakes for this operation.

The plant has a nominal capacity of 1000 tons for 24 hours, but in reality is capable of incinerating only some

750 tons when taxed to its utmost. All iron obtained from raking over the garbage is utilized by the Standard Manufacturing Co., a subsidiary of the Sanitary Reduction Works, for the manufacture of window weights. The scavengers, moreover, before delivering the garbage, search it for everything of value, such as metals, rags, bones and bottles. It is reported that the salvage amounts to $15 per wagon per month.

The buildings of the Sanitary Reduction Works are not designed or constructed in such a manner that they may be readily kept clean. Noxious odors and excess of smoke have been the cause of numerous complaints from the residents of the neighborhood, which is centrally located, and just on the border of the manufacturing district. For this reason the city undertook to construct and operate a municipal plant.

Before preparing plans and specifications a study was made by the bureau of engineering to determine the quantity and quality of garbage collected in San Francisco. The data obtained at that time have been brought to date and are here presented as Tables I to V.

TABLE I. AVERAGE AND MAXIMUM QUANTITIES OF REFUSE DELIVERED AT THE PLANT OF THE SANITARY REDUCTION WORKS

	1914
Average number of wagonloads per week day	220
Maximum number of wagonloads per week day	240
Average measured volumes of wagons, cu.ft.	139
Maximum measured volumes of wagons, cu.ft.	239
Average net weight of loads, lb.	4400
Maximum net weight of loads, lb.	11,000
Average volume of loads delivered, cu.ft.	150
Maximum volume of loads delivered by the regular scavengers, cu.ft.	450

TABLE II. AMOUNT OF REFUSE COLLECTED DAILY IN SAN FRANCISCO, ITS UNIT WEIGHT AND THE ESTIMATED QUANTITIES OF ASHES, GARBAGE AND RUBBISH IT CONTAINS

Collections One Day Each Week for 19 Successive Weeks	Estimated Quantities, Cu.Ft.			Average for the Week Unit Weight of Refuse, Lb. per Cu.Ft.	Average for the Week Collected per Week Day, Tons
	Ashes	Garbage	Rubbish		
1	4,377	47,232	126,750	29.5	435
2	3,857	47,962	128,589	27.1	404
3	3,845	50,911	124,789	27.2	405
4	5,216	57,150	118,104	28.0	419
5	5,529	65,202	105,862	27.9	408
6	4,541	63,083	109,436	28.2	413
7	8,210	55,361	111,040	30.2	434
8	13,744	58,986	106,356	30.0	445
9	20,544	64,277	90,237	30.2	437
10	22,082	51,081	107,028	28.5	426
11	21,026	51,426	94,023	29.4	406
12	21,525	57,429	97,323	29.4	427
13	18,954	69,009	93,593	31.4	471
14	14,728	61,682	91,704	33.4	466
15	13,712	67,759	97,562	33.9	502
16	14,341	74,004	85,216	33.0	474
17	12,734	66,610	97,577	31.1	456
18	17,455	63,260	93,172	31.9	461
19	17,115	62,192	96,880	32.1	470

The average amount of refuse collected per week day for the 19 weeks was 440 tons.

The weights of refuse given in the above table were obtained by weighing each load separately on a wagon scale as it was delivered to the plant of the Sanitary Reduction Works. The volumes were obtained by measuring the capacity of the wagons and estimating the excess or deficiency of the volume of the refuse contained therein. The quantities of ashes, garbage and rubbish composing the refuse were obtained by estimating by observation the relative proportion of its components as the wagon loads were dumped into the bunkers.

TABLE III. DEAD ANIMALS DISPOSED OF BY REDUCTION AT SAN FRANCISCO PER YEAR

	1907	1908	1909
Horses	1800	1420	1469
Cows	120	100	113
Dogs	4200	3692	5447

TABLE IV. AVERAGE DAILY DELIVERIES OF REFUSE TO THE SANITARY REDUCTION WORKS, 1907 TO 1914

Months	Average Deliveries, in Tons per Week Day							
	1907	1908	1909	1910	1911	1912	1913	1914
January	389	463	476	504	495	495	526	518
February	401	497	472	482	464	471	508	504
March	402	480	441	493	458	472	513	500
April	400	428	435	460	438	456	520	517
May	367	418	403	443	409	446	498	448
June	333	386	423	423	399	424	463	482
July	333	374	406	427	407	427	456	479
August	362	407	477	463	464	476	478	453
September	355	438	472	462	470	485	486	511
October	437	433	497	474	465	481	481	495
November	368	428	513	487	434	508	518	507
December	450	448	515	491	477	507	518	537
Average for year	383	433	460	467	447	471	497	497

TABLE V. TOTAL QUANTITY OF REFUSE COLLECTED IN 1911

(Estimated from data obtained from the Sanitary Reduction Works, and showing probable quantities of ashes, garbage, rubbish and manure collected, as computed from the data obtained by investigation by the board of public works.)

	Average per Week Day, Tons	Total Quantity Collected	
		Tons	Cu.Yd.
Ashes	49	15,500	27,000
Garbage	229	72,000	131,000
Rubbish	188	59,200	204,000
Manure	31	9,800	24,000
Total	497	156,500	386,000

A contract for the installation of two incinerating plants, each with a capacity of 120 tons in 24 hours, one in the Islais Creek District and one in the North Beach District, was awarded to a New York company in November, 1910, for the estimated sum of $263,216. Under the terms of the specifications the contractor guaranteed:

(1) That no nuisance would be created in the normal operation of the plant.

(2) That no odors, obnoxious smoke, or dust would escape from the chimney.

(3) That at no time during the normal operation of the plant the temperature in the combustion chambers would fall below 1250° F., and that an average temperature therein of at least 1500° would be maintained.

(4) That the residue from the furnaces would be thoroughly burned hard and be free from organic matters.

(5) That the flue dust collectors, furnaces, and combustion chambers would be so arranged that it would be unnecessary to shut down any one unit for more than 48 hours in any one week in order thoroughly to remove dust and ashes.

(6) That the pounds of refuse per hour which would be incinerated per square foot of grate area should not be less than that stated in the contractor's bid (83⅓ lb.).

(7) That the average cost per ton of each plant for incinerating refuse would not be greater than stated in the contractor's bid (profit of 25.5c. per ton).

On the basis of this guarantee, construction of the Islais Creek Incinerator was begun in 1912. The plant, as finally constructed, is housed in two buildings, one

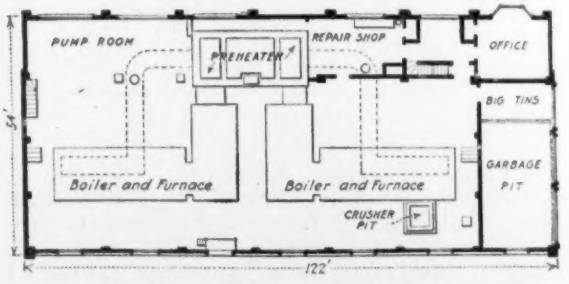


FIG. 1. MAIN BUILDING, ISLAIS CREEK INCINERATOR, SAN FRANCISCO

of which is 54x122 ft. and the other is about 25x54 ft. in plan. The larger structure (Fig. 1) covers the incinerating apparatus and the smaller contains the clinker disposal equipment and bins for the storage of crushed clinker.

Garbage is dumped into a pit situated at the east end of the large building. This pit is about 16x30 ft. at the top, and 30 ft. deep, the side walls being tapered in toward the bottom, so that the width of the pit at a depth of 25 ft. is only 6 ft. For the remaining 5 ft. the walls are vertical.

Two incinerating units have been installed with a nominal capacity of 60 tons per day. Each unit consists of a furnace of four cells with separate hoppers, grates, operating doors, clinker pit and operating mechanisms for each cell. Garbage is lifted from the pit by means of a grab bucket operated from an overhead traveling crane and delivered to a steel trough situated above the furnaces

and extending the full length of both units. In the bottom of the trough and over each cell is a steel hopper with a bottom gate through which refuse is dumped on to the burning grates.

Heated gases pass from the furnaces into the combustion chamber of the unit and then into the boiler. After leaving the boiler they pass through a preheater of vertical tubular construction into the dust-settling compartment and thence through a flue to the chimney and the atmosphere. The function of the preheaters is to heat the air drawn from the top of the inside of the building through a series of pipes or ducts and forced by means of an electrically driven fan through other ducts to the underside of the grate bars of the furnace and thence through the burning refuse to sustain combustion.

When the garbage and refuse in a cell have been reduced to ashes and clinker the grate beneath that cell is withdrawn and the contents drop into a clinker pit or chamber below, where they remain until such time as the succeeding charge of clinker and ash is ready to be dropped. The air from the preheater passes through this clinker on its way to the burning garbage and absorbs a considerable quantity of heat, which aids the combustion of material in the furnace. The clinker pit is discharged by a hydraulic ram forcing the clinker and ash out of the back end of the pit through a door which is opened for the purpose, into a closed or hooded car, which serves, by means of overhead track and trolley, all the clinker pits of both units, traveling the entire length of both settings at the back of the units. From this car, the clinker and ash are discharged through gates at the bottom into another car, which is lifted on an inclined track by means of an electric winding engine and wire cable to the top of the clinker building, where the contents are automatically dumped on to the floor over the crusher mills. A view of the clinker alley is shown by Fig. 2.

The Islais Creek Incinerator equipment also includes a General Electric turbo-generator of 75 kw. capacity,

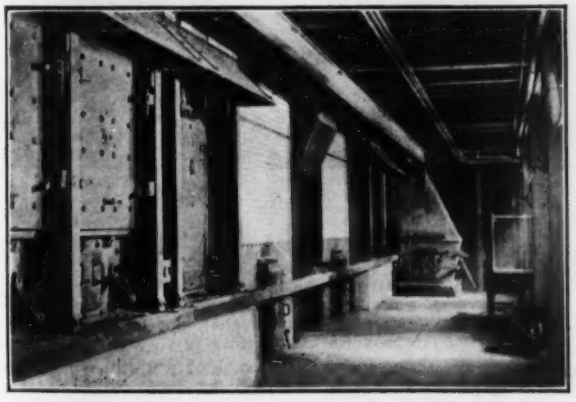


FIG. 2. CLINKER ALLEY, SAN FRANCISCO GARBAGE AND REFUSE INCINERATOR

with its switchboard and appliances, two duplex outside-packed plunger boiler-feed pumps, one oil-pumping set for supplying oil to burners under the boilers, and a hydraulic accumulator with two triplex hydraulic pressure pumps operated by electric motors to supply hydraulic pressure at about 1250 lb. per sq.in. The hydraulic pressure is used for the operation of the top gates over the furnaces, the grates in the furnaces, the rams for discharging the clinker pits, and a press for baling tins rejected from the clinker screen. The hydraulic pumps and accumulator are located in the clinker building. The generator supplies the electric current for operating two fan motors, one for each unit, the crushing rolls and screen, the incline car, the sump pump, the hydraulic-pressure pumps, all the cranes and for lighting both buildings. Fig. 3 is a view of the pumps and motors.

In the clinker pit is a dumping floor for the incline car above mentioned, a set of crushing rolls and a revolving screen which receives all the products from the crusher and delivers the various sizes of material to different bins beneath the screen. The screen and crusher rolls are driven by a motor and appropriate drive shafts, belts and chain gear. The bins beneath the screens are large enough to hold approximately one day's run and the product from the several bins may be drawn through gates and chutes into railway cars or carts as desired. The overflow from the screen, consisting principally of tins with some pieces of clinker, falls into a chute leading to the baling-press floor. On this floor is a hydraulically operated baling press into which the tins are shoveled and compressed into packages or bales about 18 in. in diameter and 6 in. thick. These have an average weight of about 70 lb. each. The wasted clinker is not baled with the tins, but is roughly separated and wheeled out and dumped over the bank.

Dressing rooms, showers and lockers for the men who operate the plant are located in the clinker building.

In August, 1913, the installation of the furnaces and mechanical equipment had advanced to such an extent as to permit of commencing operations in order to train the operators and to discover any minor defects in the machinery, and accordingly arrangements were made with the scavengers to commence delivering mixed refuse and garbage at the Islais Creek Incinerator on Aug. 28.

The plant was operated intermittently during the months of August, September, October, December, January and February, during which time a total of 2037 tons of mixed garbage and refuse was incinerated in the furnaces.

These preliminary operations demonstrated that the machinery and appliances which had been installed for the purpose of handling the clinker and ashes would have to be entirely remodeled in order to meet the requirements of the specifications and that minor modifications in the overhead traveling crane and other parts of the mechanical equipment were necessary.

The city engineer, therefore, advised the contractor that the final tests would not be started until these defects should be corrected, so the plant was shut down in February, 1914, for the purpose of making the necessary changes.

TABLE VI. ANALYSES OF SAN FRANCISCO REFUSE DURING INCINERATOR TEST

Date	Tons	Grab-buckets Hoisted	Samples Taken	Per Cent. of Moisture	Per Cent. of Combustible
Sept. 23.....	121.61	181	22	55.9	25.9
Sept. 24.....	92.13	132	22	43.1	24.9
Sept. 25.....	104.21	150	25	56.5	23.4
Sept. 26.....	109.92	143	24	52.9	26.5
Sept. 28.....	113.94	162	27	55.4	26.5
Sept. 29.....	134.30	188	30	47.7	23.9
Sept. 30.....	138.40	180	30	52.5	25.7
Oct. 1.....	110.85	156	25	48.9	28.0
Oct. 2.....	104.45	123	20	48.6	27.3
				471.5	231.2
Average for the nine days.....				52.4	25.8

After the required modifications the final test was commenced on Sept. 4, 1914, and continued until the

evening of Oct. 3, 1914. Analyses of the refuse incinerated are shown by Table VI and the results of the test as a whole are given in Table VII.

TABLE VII. RESULTS OF CONTRACT TEST OF SAN FRANCISCO REFUSE INCINERATOR, SEPT. 4, TO OCT. 3, 1914

Duration of trial in actual operation, days	26.0
Total burning hours for entire period, hr.	449.0
Average burning hours per day for 26 days, hr.	17.6
Garbage:	
Received during the period, tons	2,831.0
Average for the 26 days per day, tons	108.88
Moisture per ton @ 52.4% mean 9 samples, lb.	1,048.0
Combustible per ton @ 25.8% mean 9 samples, lb.	516.0
Water:	
Average to boilers during burning time, lb.	190,085.0
Average to boilers during shut-down time, lb.	10,060.0
Total average to boilers for 24 hours, lb.	200,145.0
Feed-water temperature, deg. F.	68.0
Evaporation Equivalent:	
Factor evaporation for burning period, lb.	1.264
Factor evaporation for shut-down period, lb.	1.19
Equivalent evaporation from and at 212 deg. F. for burning period, lb.	11,971.0
Total of equivalent evaporation from and at 212 deg. F., lb.	252,238.0
Steam:	
Pressure of gage, mean of 26 days, lb.	148.0
Temperature saturated steam, deg. F.	365.0
Temperature superheated steam, deg. F.	487.0
Degrees of superheat, deg. F.	122.0
For generator drive 28.17 lb. per kw.-hr.	9,817.0
For feed pump 20.55 lb. per 1000 lb. steam, lb.	5,914.0
Available balance for revenue, lb.	236,507.0
Power:	
Total output by generator, average for 26 days, kw.-hr.	368.5
For incineration, kw.-hr.	348.5
Cost of incineration:	
Assumed revenue from steam at 4c. per 100 lb. steam.	$94.60
Cost of labor = 17.6/22 of $66.	52.80
Assumed net profit	41.80
Cost of incineration per ton of garbage:	
Assumed revenue from steam per ton	0.8688
Cost of labor = 17.6/22 per ton	0.4849
Assumed net profit per ton	0.3839
Guaranteed profit per ton standard garbage	0.255
Corrections for excess of moisture — minus	0.0538
Corrections for excess of combustible — plus	0.0896
Corrected guaranteed profit per ton	0.291
Difference between assumed net profit and corrected guaranteed net profit per ton more than guarantee	0.0929

On the result of this test the city engineer's report is quoted as follows:

The plant does not meet the first guarantee that no nuisance is created in its normal operation.

The plant does not meet the second guarantee that no odors, obnoxious gases, smoke or dust escape from the building or chimney.

The plant does not meet the third guarantee in the requirement that the temperature in the combustion chambers shall at no time fall below 1250° F. It does meet this guarantee in that the average temperature maintained in the combustion chambers is in excess of 1500° F.

The plant does not fully meet the fourth guarantee that the residue from the furnaces shall be thoroughly burned hard and free from organic matter.

The plant fully meets the fifth guarantee that the flues, dust collectors, furnaces and combustion chambers shall be so arranged that it shall not be necessary to shut down any one unit for more than 48 hours in any one week in order to thoroughly remove dust and ashes.

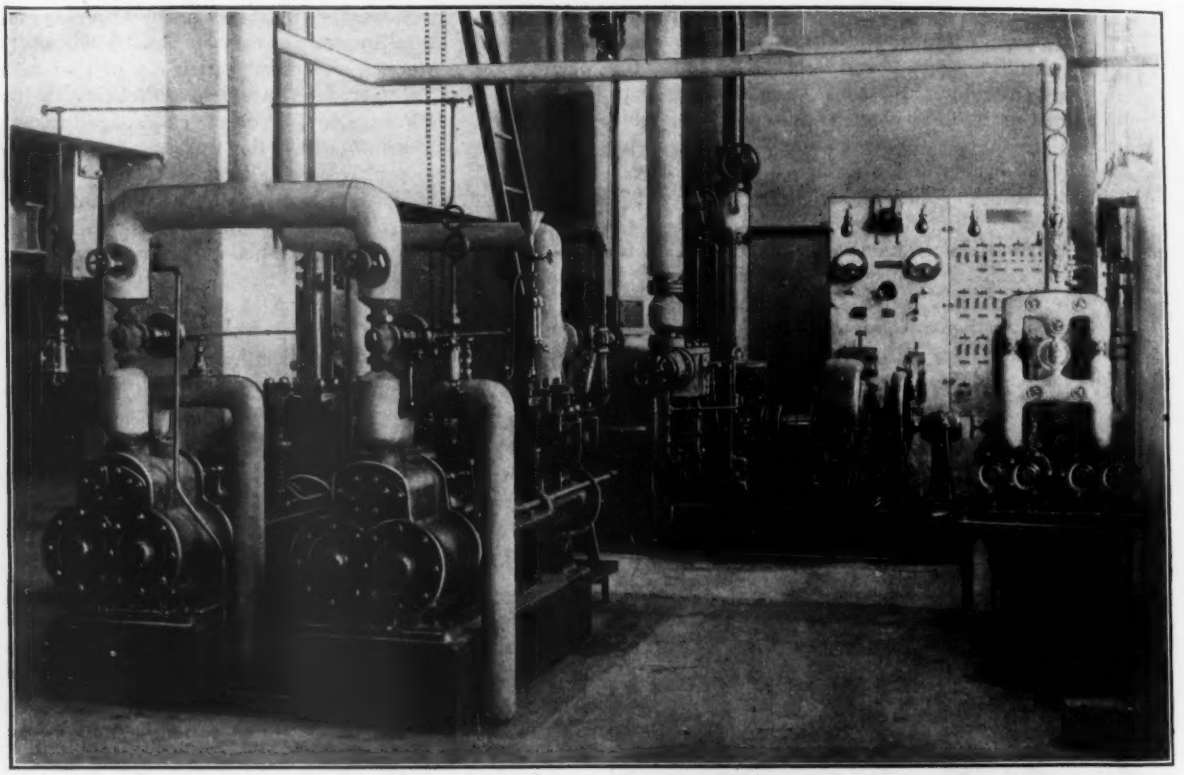


FIG. 3. PUMPS AND ELECTRIC MOTOR, SAN FRANCISCO GARBAGE AND REFUSE INCINERATOR

The sixth guarantee that the pounds of refuse per hour which will be incinerated per square foot of grate area shall not be less than stated in the contractor's bid is fully met.

The seventh guarantee that the average cost per ton at each plant for incinerating refuse shall not be greater than stated in the contractor's bid is fully met.

Acting on this report the Board of Public Works refused to accept the plant for the city.

The San Francisco Civic Center, located between Van Ness Ave., McAllister, Hayes and Market Sts., is progressing favorably. This site is ultimately to house a public auditorium, the city hall, a state building, a library, an opera house, buildings for the fire and police departments and a power house, all grouped around a central park covering two city blocks. At present the city hall and auditorium are under construction. The land for the latter was given by the City and County of San Francisco and the building was originally planned to be a gift from the Panama-Pacific Exposition Co., which agreed to furnish $1,000,000 for the purpose. The structure finally accepted is to cost $1,200,000, the additional sum being appropriated by the city.

San Francisco's Sewerage System

Previous to 1904 San Francisco's method of sewage disposal was unsanitary and inadequate. No coördinated system had been adhered to in construction. As new districts were opened for habitation a sewer would be built independent of previously existing sewers, with no other factor influencing its size and grade than to provide for the blocks in which it was constructed, and run the line down hill to the bay. In some instances beneath street crossings large brick vaults were constructed as junctions for pipe sewers. It is difficult to understand what was their supposed function. Certainly they were costly to construct, and served only as collectors of filth that should have been carried away through the sewer. The quality of workmanship was exceedingly poor. In many instances when pipe sewers were later uncovered it was found that no mortar whatever had been placed in the joints. In order to economize in the use of pipe, contractors instead of inserting the spigot of one pipe into the bell of the adjoining one often allowed a space of several inches between the two. There were over 125 outlets discharging domestic sewage along the waterfront, where it was often washed back upon the shore.

To remedy these conditions, in 1899 the Board of Supervisors appointed a commission consisting of C. E. Grunsky, C. S. Tilton and Marsden Manson to prepare plans and submit estimates for an adequate sewage-disposal system. In the construction of the system as it exists today the recommendations of this committee were followed, with various modifications.

Separate System

Both the "Separate System," in which only domestic sewage flows through the conduit, and the "Combined System," in which storm water also enters the sewer, have been constructed, each in the district to which that particular type is best adapted.

In the low-level districts of the eastern portion of the city the separate system (Fig. 1) was constructed for house sewage. To provide drainage for deep basements and a flow free from tidal influence, sanitary sewers were laid at considerable depth. It was, therefore, necessary to provide a concrete-lined sump and a pumping station at Commercial and Drumm St., whence sewage could be raised from the separate domestic system into the large combined sewer that discharges opposite North Point. The pumping station is equipped with two 6-in. centrifugal pumps of vertical-shaft, balanced-suction type, each with a capacity of from 650 to 750 gal. per min. under heads varying from 15 to 25 ft.

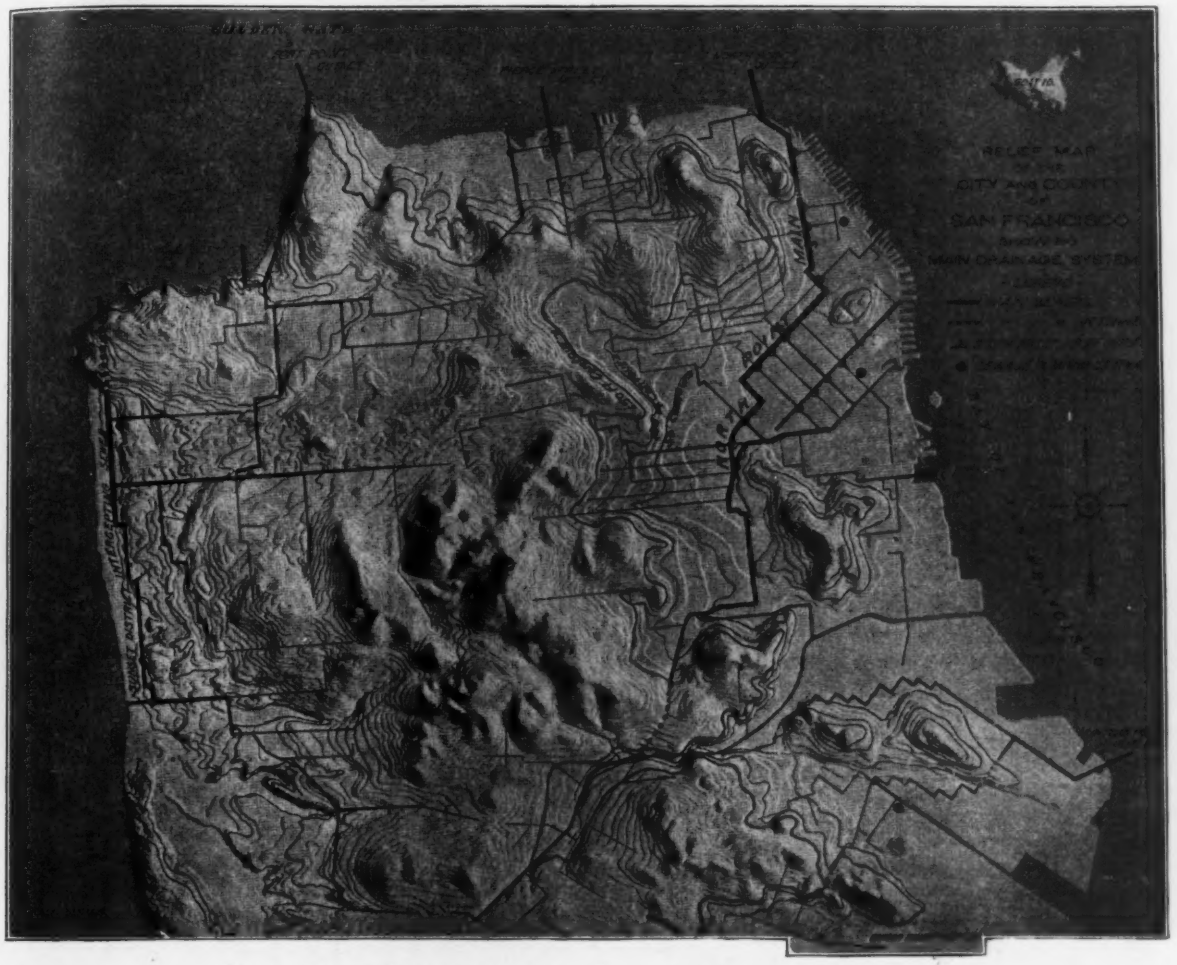


Fig. 1. Relief Map of Main Sewerage System of San Francisco

The average rate of domestic sewage contributed was assumed as 70 gal. per 24 hr. per person or 0.109 cu.ft. per sec. The maximum rate of flow was taken as 50% in excess of the average or 0.163 cu.ft. per sec. per 1000 inhabitants. Besides this an allowance was made for ground-water infiltration because even with the best construction pipe sewers cannot be made absolutely impervious. As many of the lower portions of the city, in which the separate system has been constructed, are subject to

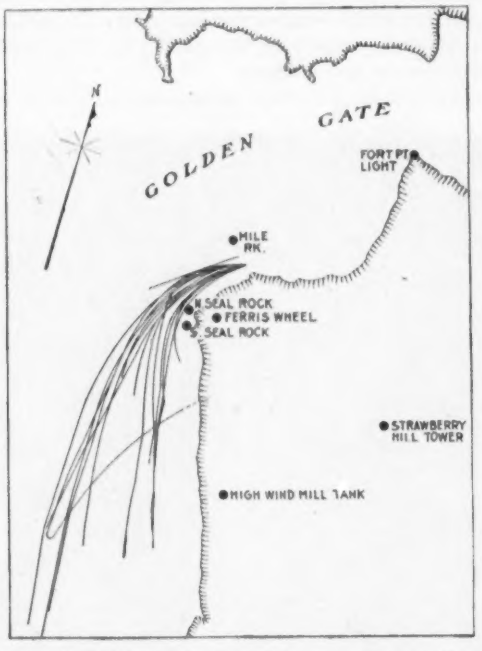


FIG. 2. OCEAN CURRENT OBSERVATIONS, SAN FRANCISCO

tidal influence, the allowance for ground-water infiltration was liberal, amounting to 0.003 sec.-ft. per acre. In the upper districts 0.001 sec.-ft. per acre was allowed.

That the dilution of San Francisco's sewage is amply sufficient to render it unobjectionable may be seen from the following figures:

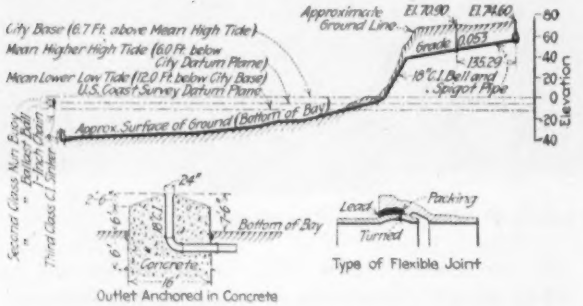


FIG. 3. BAKER'S BEACH OUTFALL SEWER, SAN FRANCISCO

With a population of 1,000,000 the total water consumption will not exceed 70,000,000 gal. daily or 109 sec.-ft. This may be taken as the approximate amount of domestic sewage that will be daily discharged into the Bay. The ordinary tidal prism of San Francisco Bay is 97,500,000,000 cu.ft., while the minimum flow from the tributary rivers in 7 hr., the duration of an average tidal outflow, is 2,500,000,000 cu.ft. Thus the minimum tidal flow through the Golden Gate is 343,000,000,000 cu.ft. in 24 hr. This varies in proportion to the range of tides, which as published by the United States Geological Survey in 1899 is approximately as follows:

	Ft.
Mean range of tides	4.1
Mean range of spring tides	5.1
Mean range of neap tides	3.1
Mean range of great tropic tides	5.5
Maximum range in 24 hours	7.2
Minimum range in 24 hours	0.8

From the above data it follows that the amount of sewage passing out through the Golden Gate will never exceed 4 parts in 10,000 parts of salt water and will ordinarily be less than 3 parts in 10,000.

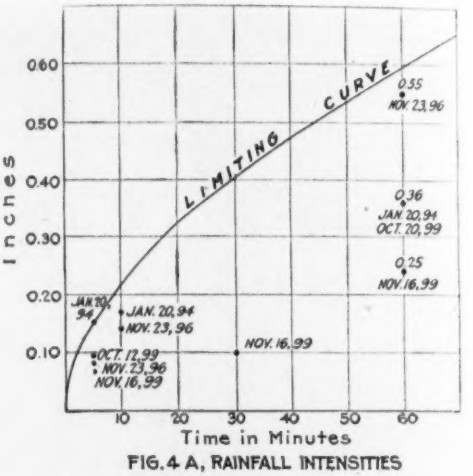


FIG. 4 A, RAINFALL INTENSITIES

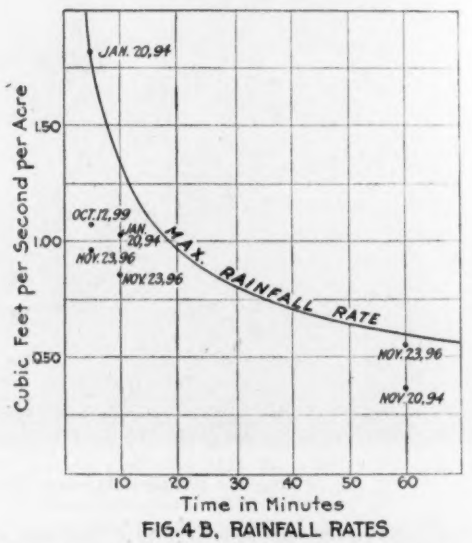


FIG. 4 B, RAINFALL RATES

FIGS. 4A AND 4B. RAINFALL INTENSITIES AND RAINFALL RATES AT SAN FRANCISCO

Separate sanitary sewers are constructed of salt-glazed, vitrified ironstone pipe, with joints first calked with oakum and then filled with a 1:2 cement-mortar. In soft ground, piles were driven almost to refusal at 10-ft. centers along the line of trench to provide a suitable foundation. All pipe on a pile foundation was completely surrounded by heavily reinforced concrete.

Before determining points of outfall for conduits carry-

ing domestic sewage an elaborate series of float observations was made. Floats were dropped at intervals, first near the shore line and later some distance therefrom, along the entire waterfront. The floats were followed in a steam launch and their paths accurately platted. In this way were gathered many valuable data concerning the tidal currents in the bay, through the Golden Gate and along the ocean beach. A plat of the paths of one series of floats dropped in the vicinity of Mile Rock near the storm outlet of the Lower Sunset sewer is shown in the accompanying diagram (Fig. 2). It will be noted that out of some twenty floats only one was washed back on shore. Nevertheless, on the basis of these observations it was decided to discharge no house sewage into the channel at this point, but in dry seasons to pump such sewage from the Mile Rock combined sewer and discharge it into Golden Gate Straits opposite Fort Point, where it would be rapidly diluted and removed by the very swift tidal current.

For this purpose a sewage-pumping station is being constructed at 48th Ave. and Fulton St. The pumping equipment will be housed in a reinforced-concrete vault beneath the street, 16x24½ ft. in plan and 36 ft. 7 in. high in the clear. The station will be arranged in two separate units. Each unit will consist of two 10-in. centrifugal pumps operated by a 200-hp. vertical motor at a speed of 850 r.p.m. The total capacity of the two units will be 2000 gal. per min.

From this station sewage will be pumped through a 24-in. bell-and-spigot cast-iron pipe against a static head of 146 ft., a distance of 6730 ft., whence it will flow to the Baker's Beach outfall. This outlet is located 800 ft. from the shore line and the discharge is 32 ft. below mean low tide. The outfall structure is of concrete and is shown by Fig. 3. From the shore to the outlet sewage is carried by gravity head through an 18-in. cast-iron bell-and-spigot pipe with flexible joint of the type shown in Fig. 3. When completed a nun buoy will indicate the location of the outlet.

A sanitary sewer of unusual type was laid in the southern end of the city. For over a mile the Ingleside sewer lies within the drainage area of Lake Merced, whence San Francisco derives a portion of its domestic water-supply. The quality of the water from this source is not as good as from any of the other reservoirs which supply the city. To guard it from further contamination, cast-iron pipe was used as a conduit. This was 24 in. in diameter, with bell-and-spigot joints calked with 2½ in. of oakum packing and 1½ in. of lead.

Since the revised system of sewage disposal has been constructed the number of conduits discharging domestic sewage into the bay has been reduced to five, and all the points of discharge are some distance out from the shore line.

Combined System

By far the larger area of the city is provided with the combined system. In calculating the requisite size of combined sewers, domestic sewage, storm water and ground-water infiltration were all provided for. For the content of domestic sewage the same factors were used as for the seperate sanitary system. For ground-water infiltration 0.002 sec.-ft. per acre infiltration was assumed.

In calculating for storm water a careful study was made of all existing data on local rainfall and runoff. It was found that for a period of 50 years, during only 22 storms had rain exceeded 2 in. in 24 hr., and only once was as much as 4.5 in. in 24 hr. experienced. The maximum five-minute rainfall ever known in San Francisco was 0.15 in., and for a ten-minute duration 0.17 in. For a period of one hour the most severe rainfall recorded gave 0.55 in. On the basis of these data a provision for 5 in. of rainfall in 24 hr. seemed ample. In Fig. 4A is shown the rate curve adopted for storms of various duration.

The storm-water runoff varies with the density of population. Even in thickly settled districts, where all the

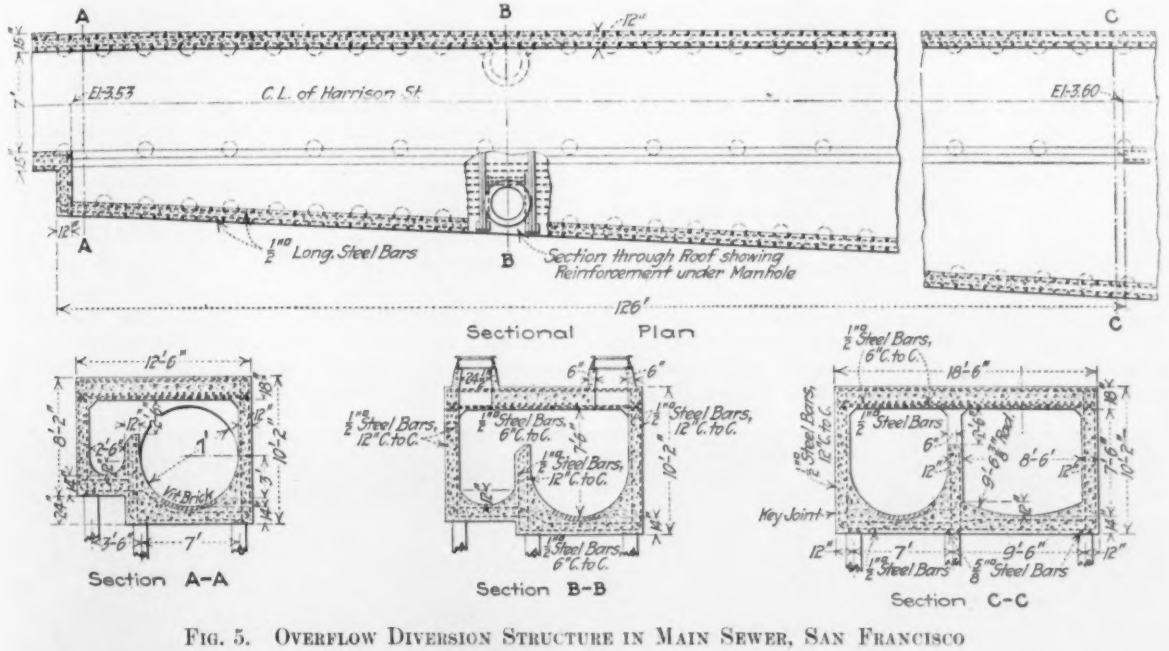


Fig. 5. Overflow Diversion Structure in Main Sewer, San Francisco

streets are paved and almost all the remainder of the area tightly roofed, the maximum runoff seldom exceeds 75% of the maximum rainfall. For a population of 30 per acre a runoff of 30% was assumed, and for districts having 100 residents per acre the runoff was taken as 75% of the rainfall, with an almost uniform rate of increase between these limits.

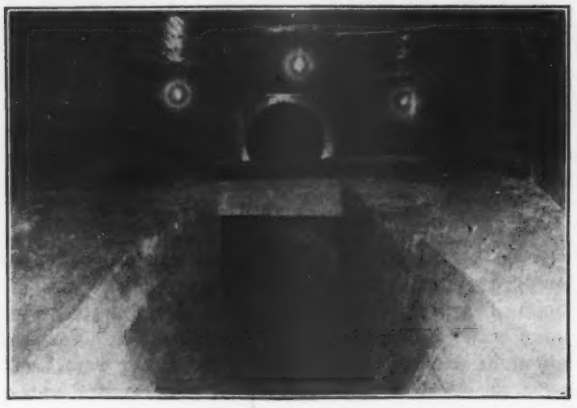


FIG. 6. STORM-WATER OVERFLOW IN SAN FRANCISCO SEWER

The time element was an important factor in calculating conduit capacity and in determining critical points along a sewer line at which dimensions should be increased. Adding from 3 to 5 minutes which it would require for rainfall to reach the conduit to the period necessary for it to flow in the conduit from the most remote portions of the district to the point under investigation, a definite time interval was obtained. The rate curve shown in Fig. 4B was then used to establish the maximum rainfall for that interval. Assuming that the entire district above the point in question contributed runoff waters, by multiplying the number of acres therein by the number of cubic feet per acre obtained from Fig. 4B, the conduit capacity necessary at the definite point could be obtained and the requisite dimensions calculated. A liberal safety factor was applied to these.

STORM-WATER RELIEF OUTLETS

As already stated it is essential that domestic sewage be discharged at a considerable distance from the shore, at such points that its dilution and removal by tidal currents will be assured. It is unnecessary and would be extremely uneconomical, however, to carry storm water the full distance to these points of discharge as it would necessitate conduits of excessive size. For this reason in the large combined sewers relief outlets have been constructed. The combined sewers below these outlets are sufficiently large for sewage proper, soil water and runoff from a rainfall of ¼ in. in 24 hr. over the contributing district. Flow through storm-relief outlets is therefore infrequent, and is necessarily comparatively clean rain water. This is discharged at ten points along the bay shore line.

Storm-water outlet structures are of two types. The more common consists of a flat-roofed chamber, wider than the sewer proper, and containing two channels separated by an overflow weir. One channel is a continuation of the sewer proper; the second leads to the auxiliary storm-water sewer. At times of severe rainfall the storm-water excess flows over the weir into the relief sewer and through it directly to the bay. Such a diversion structure is shown by Fig. 5 and a second type of diversion structure is shown by Fig. 6.

STORM AND COMBINED SEWERS IN EASTERN DRAINAGE AREA

The topography of San Francisco is exceedingly uneven, as shown in Fig. 1. The city is located at the northern extremity of a peninsula 35 mi. in length. On the west it terminates at the shore of the Pacific Ocean and on the north and east is bounded by San Francisco Bay. A detached spur of the Coast Range divides the area into two main watersheds, one sloping toward the ocean on the west, the other toward the bay on the east. Secondary spurs subdivide each watershed. The eastern drainage area has five secondary basins, namely, Visitacion Valley, Islais Creek, Mission Creek, the east Bay Shore and the North Bay Shore. The western watershed is subdivided into three separate basins, namely, the Ingleside, the Sunset and the Richmond districts.

FIG. 7. INTERIOR VIEW

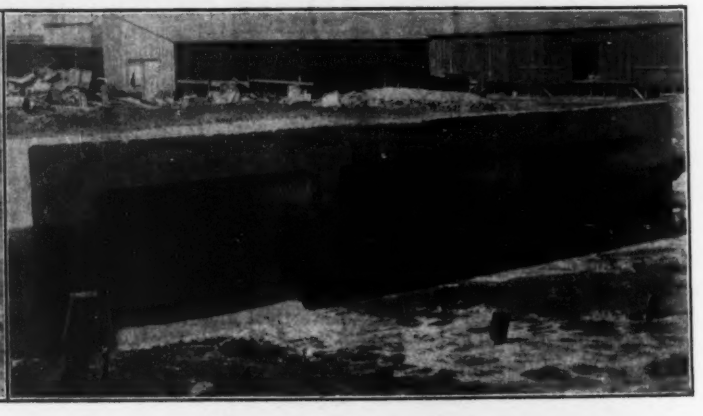


FIG. 8. EXTERIOR VIEW

VIEWS OF DIVISION ST. SEWER OVERFLOW, SAN FRANCISCO

The largest and most important sewer in the eastern drainage area is the North Point main, over five miles in length, which extends from the Islais Creek district to the foot of Grant Ave. This is of the combined type and serves an area of approximately 12,000 acres, and 80% of the population of the city. Storm-relief outfalls from the North Point main are constructed at the intersection

of Mission St. with Islais Creek; at Fifteenth and Harrison St.; on Howard St. at Fifth, Sixth and Seventh St.; at Second and Mission St.; in Sansome St. at Commercial St., Jackson St. and Greenwich St.

When completed the North Point sewer will be approximately 6 mi. in length. The grade is only 1 ft. in 2000.

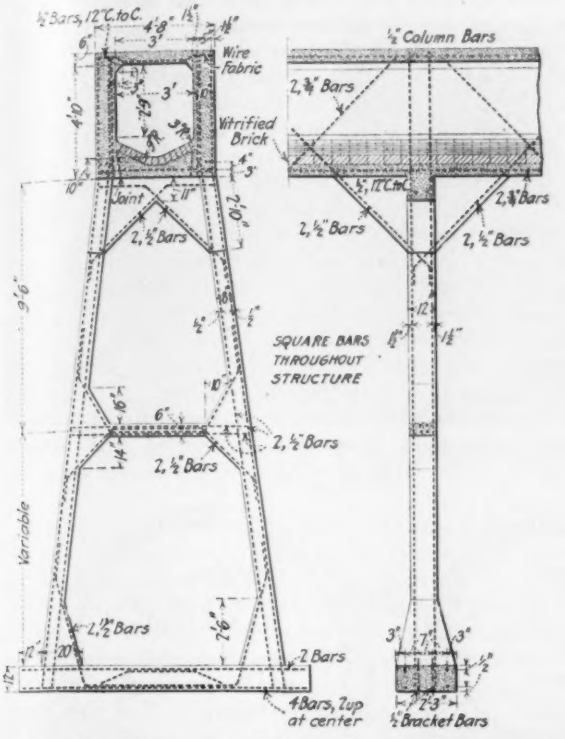


FIG. 9. MONOLITHIC COMBINATION SEWER AND TRESTLE, SAN FRANCISCO

With the large constant volume of flow this will be sufficient.

A part of this conduit is in tunnel, which extends along the line of Sansome St. from Pacific St. to a point beyond Union St., a distance of 1409 ft. through metamorphic schist and weathered sandstone shale. For construction, four vertical shafts were driven 343 ft. apart at the street intersections on the line of the bore. Drifts were driven both ways from the two center shafts. Concrete was mixed on the surface and passed through a chute to cars in the tunnel, whence it was conveyed to the heading and placed by shovel in the forms.

The most important storm-relief outfall in the district east of the boundary ridge is the Division St. sewer. This structure comprises three compartments, each 8x9 ft. in the clear, and has a total capacity of 1800 sec.-ft. at high tide. It is constructed in the former bed of Mission Creek, which is composed of slimy silt very unsuitable for a foundation, and the structure therefore required a forest of piles beneath it to obviate the danger of settlement. The terminal yards of the Southern Pacific Co. extend above the sewer. For this reason it was necessary in the design to provide for carrying the weight of the heaviest type of consolidation locomotive, with a safety factor for impact stresses. This outfall has been in use for several years and there are no signs of cracking or settlement, and no infiltration of the surrounding ground water. Fig. 8 shows an interior and exterior view of the structure.

Another large main sewer traverses the northerly portion of the eastern drainage area. This is laid in Pierce St. and serves the northern slope of Pacific Heights and the Harbor View district, including the grounds of the Panama-Pacific Exposition. A large storm sewer in Baker St., disturbed by the earthquake of 1906, has been reconstructed to take care of the heavy storm runoff from the steep incline of Pacific Heights. As this discharges near the shore line, sewage proper is diverted into the Pierce St. outfall, which is located beneath the bay at a considerable distance from shore.

A unique type of sewer has been constructed in the southern portion of the eastern watershed near Ocean View. In this district, although official elevations have been established, streets have not been graded. On the

FIG. 10. VIEW OF MONOLITHIC SEWER AND TRESTLE AT SAN FRANCISCO

line of one street the ground-level elevation is some 30 ft. below the official grade to which it will later be raised. It was therefore necessary to build a sewer conduit whose invert is over 20 ft. above the ground surface.

This structure is a monolithic combination of culvert and trestle, as shown in vertical section by Fig. 9 and by the view, Fig. 10. In its construction the reinforced-concrete footings of the trestles were first placed. When these had set, the concrete in each bent from the footing to the under side of the conduit was deposited in one

continuous operation. When the bents had been finished the concrete invert was poured, and after the concrete had set the invert was lined with vitrified brick. The sidewalls and top were then placed in one continuous operation between adjacent bents. No joints, either horizontal or vertical, were permitted in the invert, sides or top of the culvert except over the centers of concrete trestle bents.

Storm and Combined Sewers in Western Drainage Area—Along the ocean beach the breakers are always high and form at a considerable distance from the shore. To construct an outfall beyond their influence would be impracticable, so the entire storm flow of the western drainage area is carried to the northern end of the peninsula through the Sunset District sewer. This conduit varies in size from 24 in. to the largest section shown in Fig. 11. The lower portion will be in tunnel for 4450 ft., through a hard sandstone formation. Due to protracted controversy with owners of the foreshore before the right-of-way for the outfall could be secured, the upper sections were built first and the outfall portion is now being completed.

Runoff from all except the very heaviest storms will be carried through the tunnel. On occasions of exceptional downpour, overflow structures will operate to relieve the sewer. It is estimated that these overflows will not be brought into use more than three or four times a year.

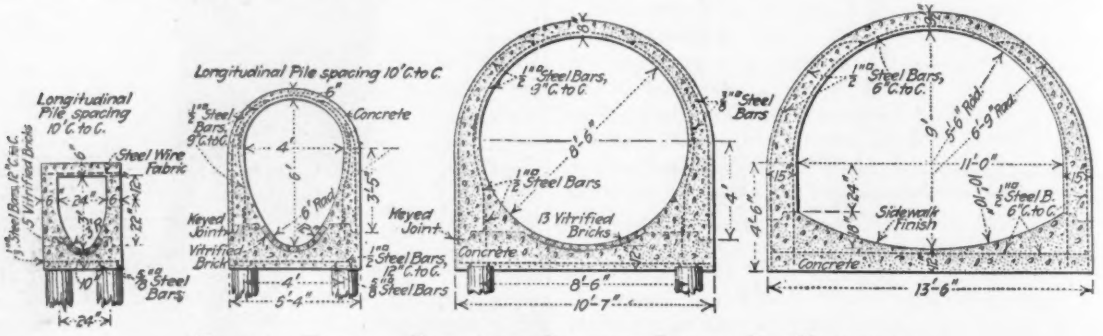


Fig. 11. Types of Reinforced-Concrete Sewers, San Francisco

Two of the subsidiary basins of the western drainage area, namely, the Ingleside and Sunset districts, are provided with combined sewers that discharge into the Lower Sunset main. The total area ultimately contributing sewage to the Sunset sewer is 6918 acres. The Richmond district has a separate storm-water outlet at Baker's Beach, and sanitary sewage will be carried to the cast-iron submerged outlet already described.

Construction

The Bureau of Engineering has been particularly successful in securing a uniformly high standard for construction work performed under its direction. The system of inspection has been rigid but not unreasonable. The personnel of the inspection force is exceptionally high, being composed almost exclusively of graduate civil engineers. Contractors have found that the most economical policy is to perform the work conscientiously and with minute regard for detail. Not only has field inspection been thorough, but numerous samples of all material used in construction have been tested in the completely equipped laboratory operated by the bureau.

In constructing large reinforced-concrete sewers various methods have been adopted by different contractors. A general outline of the plan that proved most efficient follows:

Where a pile foundation was required piles were driven before the trench was excavated. This was not wasteful, for when the butt reached the ground level a follower was placed upon the pile, which could then be driven as far as desired and the follower removed. On any contract the average pile cutoff seldom exceeded 2%.

Excavation was then carried to grade. In soft wet ground an orange-peel or clam-shell dredge was used most effectively. This would be mounted on transverse timbers and skidded ahead as the trench was excavated. In hard ground a steam shovel proved very satisfactory, while in compact clay formation scraper buckets or buckets that were loaded by hand and lifted from the trench by a steam hoist were used economically.

In timbering deep trenches longitudinal rangers, usually 8x8 in. by 16 ft. in length, were braced by 8x8-in. transverse cross-pieces, and 3-in. tongued-and-grooved vertical lagging driven behind the rangers, either with mauls or with a steam lagging hammer.

In wet ground an ironstone pipe underdrain was laid with water-tight joints and surrounded with broken stone, a 2-in. layer of which was also spread over the bottom of the trench. Vertical tees to project through the concrete invert were inserted at 200-ft. intervals, in order that the underdrain could be filled with sand and cement after the completion of the sewer.

Forms for the invert were then accurately set. For the concrete, the specifications provided a mixture of 1 cu.ft. of cement to 5 cu.ft. of rock, with enough sand to fill the voids in the rock. This was mixed by machine, which could be moved along the trench as work progressed. Before the concrete in the invert had set steel dowels were inserted, to which the reinforcing steel for the sides and arch was then attached. The invert was lined with vitrified brick, laid flat with a ¼-in. cement-mortar joint. Extreme care was taken in laying the brick invert to exact grade. At 10-ft. intervals one brick was set to exact elevation with a wye-level. A string was then stretched taut over the grade bricks and a template used in laying the remainder.

Concrete sides and arch were placed in one continuous operation. When they were completed and the forms removed the interior surface was given a brush mortar finish. Before any contract was accepted by the city it was subjected to thorough inspection by the resident engineer, the chief assistant city engineer and a member of the Board of Public Works.

Street Pavements, Roads and Boulevards

With its peculiar topographical features, San Francisco presents to the highway engineer probably as many difficulties to a proper design of pavements as any other large American city.

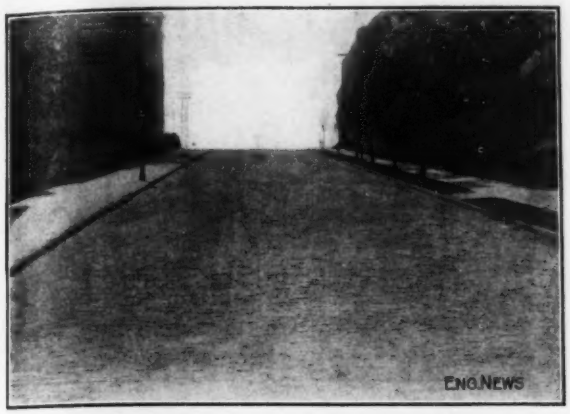


FIG. 1. RESIDENCE STREET ON A STEEP GRADE PAVED WITH SPECIAL BRICK

GRADE AND OTHER PROBLEMS—Especially is this true in the matter of grades. For example, in one of the most thickly populated sections of the city—Kearney St., from Vallejo to Broadway—a block paved with cobbles has a gradient of 29.8%. On Fillmore St., where a double-track electric-car line is operated, for about two-thirds of the distance between Vallejo and Green St., which is also paved with cobbles, the grade is 26.5%. On Chestnut St., between Polk and Larkin St., which has just been graded, the gradient for part of the block is 55.5%. There are many paved streets in the city whose gradient exceeds 20%.

A problem of an entirely different nature presents itself in that large filled-in section of the city where property values are exceedingly high and where most of the large business interests are centered. The prevention of pavement subsidence is here a serious problem.

There was little thought for the future in the early periods of San Francisco's development and no well conceived plan, either in the location, alignment or gradient

FIG. 2. TYPICAL COBBLESTONE ON STEEP GRADE STREET

of the streets, or a proper selection of pavements. Its history in this respect is not unique. It is like that of nearly every other large American city. Nor were conditions materially improved until a new city charter went into effect on Jan. 8, 1900.

REORGANIZATION OF PUBLIC WORKS—Following the adoption of this charter a board of public works was established, which in turn appointed a city engineer, and only since that time have definite plans in the treatment of the city's pavement needs been followed.

One of the first steps was to install an uptodate engineering laboratory, equipped with the most modern apparatus for the testing of paving and other engineering materials. This department has been constantly improved until at the present time it is considered one of the best engineering laboratories west of the Rockies.

Many difficulties were experienced in the changing from the old to the new methods. The public had to be educated gradually. Politicians of the old school did not take kindly to the new and scientific way of designing and laying pavements. These, together with some of the paving contractors, did all in their power to hinder development, but their opposition was finally overcome.

TYPES OF PAVEMENTS

California being the largest oil, asphalt and bituminous rock producing state in the union, it is natural that the

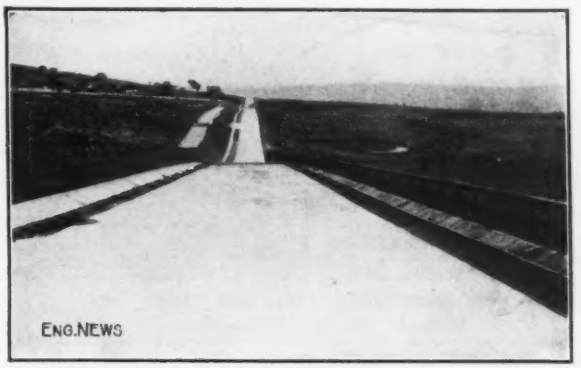


FIG. 3. PORTION OF JUNIPERO SERRA BOULEVARD WITH 3-IN. ASPHALT SURFACE

majority of this city's permanent pavements should be either bituminous rock or asphalt. Availability of supply has much to do with deciding the type of pavements that predominate in any locality.

BITUMINOUS ROCK—Formerly, the bituminous rock, as it came from the mines, was placed in closed kettles and reduced to a powder by the simple, though undesirable, agency of steam. This resulted in an excessive moisture content.

The material was then spread on the street—with disastrous results in many cases. No particular attempt was made to grade the material properly as it arrived from the mines. It was a matter of guess whether on any particular block the property owners would get a hard, medium or soft grade of bituminous pavement. Often the only foundation was a badly drained macadam or the irregular surface of an existing cobble pavement.

This same material is now handled in an efficient manner, being properly graded and reduced by the action of heated dry air. Recently, however, most of the street

pavements that have been laid in this city have been of sheet asphalt.

SHEET ASPHALT—Some of the chief investigations of the chemist in charge of the engineering laboratory have been made on California asphalts, asphaltic mixtures and various combinations of binders and wearing surfaces. Every effort has been exerted to obtain the best grade and combination of ingredients to suit particular conditions. After a long series of experiments very satisfactory results have been obtained. The following cases will be cited as illustrative of the most recent and best examples of what has been attained in the use of this material.

GEARY ST. PAVEMENT—On Geary St., from Market St. to Van Ness Ave., on which there is fairly heavy vehicle traffic, an asphalt pavement was laid for the entire width of the roadway, excepting the header blocks on either side of the rails on the municipal railroad, and the 26-in. basalt block gutters.

This pavement was laid on a standard 6-in. cement concrete foundation and consisted of a 2-in. asphaltic binder course and a 1½-in. asphaltic wearing surface. The crown was made much flatter than those used formerly.

One of the most common mistakes previously made in the design of street crowns for asphalt pavements was their excessive height, with the inevitable result that the material thinned out at the crown and increased in thickness on the gutter area, as might be expected with the viscous material of this nature under a pressure of traffic accompanied by an increase of atmospheric temperature. There has been no appreciable rolling or creeping of this Geary St. pavement, and none is expected.

LIGHT TRAFFIC STREETS—In the rapidly growing outlying districts where the traffic is of a lighter nature, consisting mainly of light motor vehicles and delivery wagons, a thinner section of asphalt surface has been decided upon for recent pavements. For example, ten blocks at the western end of Lincoln Way, in front of Golden Gate Park, were recently paved with asphalt, consisting of a 2-in. asphaltic wearing surface on a 6-in. cement concrete foundation. This completed the paving of a main trunk road 53 blocks in length, from the Panhandle to the beach. This will be one of the most important avenues in the Sunset district.

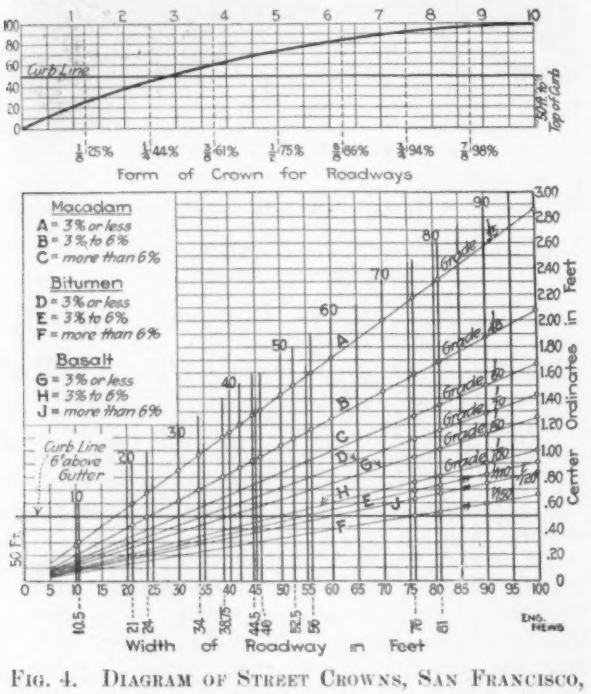


FIG. 4. DIAGRAM OF STREET CROWNS, SAN FRANCISCO, CALIF.

FIG. 5. COBBLESTONE PAVEMENT ON 31.6% GRADE, 22ND ST. AND VICKSBURG ST.

BOULEVARDS—Another good example of asphalt pavement constructed recently is that along Ocean Ave., from Plymouth Ave. to its junction with the Junipero Serra Boulevard and Sloat Boulevard. This pavement extends over the entire width of the roadway, which is 60 ft. Along the center is a double-track electric road, which leaves a clear width of roadway of 22 ft. on either side of the tracks, for vehicular traffic.

The pavement consists of a standard 6-in. cement concrete foundation and a 2-in. asphaltic wearing surface. This construction filled a long-felt want, for before it was undertaken the above roadway was a series of ruts in the summer and mudholes in winter. The old alignment and grade were unsuitable, and it was necessary to substitute for many sharp angles and arcs long horizontal and vertical curves.

The paving of this stretch of work has transformed one of the worst paved streets into one of the best, and has contributed to increase property values along its line. The extreme west end of this pavement terminates at the junction of the Sloat Boulevard and the Junipero Serra Boulevard, two of the important trunk lines of the city's rapidly growing boulevard system.

The most important paving contract undertaken by the city during the last fiscal year was the repaving of the Junipero Serra Boulevard, a stretch of roadway 1.6 miles in length. On June 30, 1914, about three-fifths of the entire work has been constructed.

Before reconstruction this boulevard consisted of a macadam roadway 25 ft. in width with a very high crown, dangerously low on the sides, and many portions were in a more or less disintegrated condition. The road followed in general the natural undulating surface of the ground.

In reconstruction the first step after the completion of the survey was to correct the existing grade by eliminating sharp verticals and introducing in their place long and smooth curves. The grade was straightened as far as possible without making heavy cuts or fills which were

prohibitive, as the amount of money available for this construction was very limited.

The paved portion of the roadway is 25 ft. in width with 5-ft. rock shoulders on either side and slopes on fill of 1½ on 1. Gutters are 5 ft. wide and 22 in. deep. At stated intervals concrete culverts provide for the diversion of storm water. A flat crown was adopted for reasons already explained, and because the longitudinal grade amply provides for drainage.

The base is of standard cement concrete, 6 in. thick, with the sides raised to 8½ in. and made 6 in. wide, so as to inclose the asphalt pavement on top and prevent creeping. The concrete is covered with asphaltic binder 1½ in. thick, and over this is a 1-in. asphaltic wearing surface.

ments. These bricks are laid on a concrete base and the interstices filled with cement mortar containing two parts sand to one of cement. While this pavement is only in the experimental state at the present time, indications are that it will give excellent results.

Other Types of Pavement—At the present time street specifications are being entirely revised by the City Engineer's office and will, when completed, embrace all of the best modern pavements, including concrete, asphalt, creosoted wood block, vitrified paving brick, bituminous rock, basalt block and others.

Considering the serious handicap imposed by previous faulty construction and the damage done to pavements by the fire of 1906, San Francisco's recent progress in pavement has been remarkable. Its paved streets include:

Fig. 6. Lutz Asphalt Surfacers at Work

The thickness of this pavement is much greater than any recommended or constructed by the State Highway Commission, and in durability and excellence it will be superior to any of the state highways.

The owners of St. Francis Wood, an adjoining tract, have recently received a permit to reconstruct Corbett Road, where it fronts on their several properties, for a distance of approximately 6000 ft. Contract has been let for the laying of an asphalt pavement 40 ft. in width for the entire length. This road adjoins the Junipero Serra Boulevard at Ocean Ave., and will be a very desirable addition to the Boulevard system.

A mile or more west is the 19th Ave. Boulevard, one of the oldest of the system. It forms a direct connection between Lincoln Way and the Sloat Boulevard, and is about 3¾ mi. in length. While at present its surface is almost entirely of macadam, if the present plans of the Board of Works are followed, it will not be long before its entire length is covered with a sheet-asphalt pavement similar to that described above.

Hard-Burned Vitrified Paving Brick—A recent innovation has been the selection of a hard-burned vitrified paving brick with irregular and pronounced kiln marks, to replace the unsightly and irregular cobble pave-

3,758,300 sq.yd. of bituminous rock pavement.
1,403,000 sq.yd. of asphalt pavement.
2,233,000 sq.yd. of basalt block pavement.
248,200 sq.yd. of cobblestone pavement.
10,600 sq.yd. of vitrified brick pavement.

Maintenance of Asphalt Pavements—It will be noticed from the foregoing table that the yardage of bituminous rock and asphalt pavements is over twice as great as the combined basalt-block, vitrified-brick and cobblestone surfaces. The maintenance of such a large area of smooth pavement is a serious problem.

Since 1913 three Lutz surfacing machines have been used with satisfactory results. The cost of resurfacing with Lutz surfacers, including repairs and royalties, amounts to 5⅓c. per sq.yd. The average force required for each machine is one foreman at $5 per day, one engineer at $6 per day and 14 laborers at $3 per day. An average of 1150 sq.yd. of pavement are resurfaced daily.

The leased price of each machine is $1800 with the understanding that a minimum amount of repair work of 10,000 sq.yd. per year must be performed. This amounts to $500 yearly.

The speed with which a street paved with asphalt can be resurfaced is of great importance in the business section of the city.

The Stockton Street Tunnel in San Francisco

On Apr. 11, 1913, a contract was let to the Jacobsen-Bade Co., for the construction of a tunnel in Stockton St., extending from Bush St. to a point 182 ft. south of the center line of Sacramento St. Work was begun several months later and was delayed by interference through the tardiness of various property owners who had encroached on the sidewalk space.

The length of the completed tunnel is 911 ft., from portal to portal, with an approach 138 ft. long on the north and 275 ft. on the south. The arch is oval-shaped and the width at the springing lines is 50 ft. in the clear. Of this width, 36 ft. is occupied by the roadway, in the center of which tracks for the municipal railroad have been laid. A sidewalk 6 ft. 6 in. wide accommodates pedestrians on either side of the tunnel. The height of the arch above the curb is 18 ft. in the clear.

Funds for the work were obtained by assessment of the property benefited. The proportionate amounts chargeable to each portion of lands within the assessment districts were determined by appraisers working under the direction of the City Engineer's office. The tax per square foot varied according to the area of the parcel assessed, its proximity to the portal, the direction of traffic, and whatever other local conditions tended to influence its probable increase of value.

Excavation for the approaches was in a clay shale formation. Three drifts, each 6x6 ft. in the clear, were run for the entire length of the bore before any of the lining was placed. The rock was next stoped out between these drifts and the specially designed timber framing set. Due to the flatness of the arch and the small distance between the extrados and the ground surface, together with the fact that many deep trenches have been excavated in the surface of the street above, thus loosening the material, practically the whole dead weight of rock between the arch and street surface above had to be supported during construction by the timber framing. Concrete stulls 5 in. in diameter carried the weight of the roof to an 8-in. I-beam bent to the curve of the intrados. The advantage of using concrete stulls was that they could be left in their original position when the overbreak was being filled with concrete, thus minimizing the danger of a cave-in when the falsework was finally removed.

Due to the severe conditions above stated, however, a chimney of loose material caved in the east drift, temporarily blocking progress. A different type of timber lining was then adopted by the contractors. Instead of the curved steel I-beam, heavy longitudinal crown bars were substituted and these proved perfectly satisfactory.

FIG. 1. NORTH PORTAL, STOCKTON ST. TUNNEL

Excavated material was hauled from the tunnel on cars pulled by an electric locomotive equipped with two 17½-hp. motors operated at 250 volts. On reaching the open cut these cars were run out on an elevated trestle and discharged into bunkers, beneath which motor trucks could be loaded to remove the material.

Concrete for the tunnel lining was placed by the pneumatic process, a specially designed patented system being employed. The mixing plant was located in an open cut near the south portal. Sand and stone were supplied by gravity from material bins above, into which motor trucks discharged directly from the street level. The placing machine was located about 8 ft. from the mixer. An 8-in. discharge pipe led from the bottom of the pneumatic drum to the section being concreted. The compressor

had a capacity of 1250 cu.ft. of free air per minute, against a pressure of 115 lb. and was driven by a 200-hp. motor. Under ordinary conditions a batch of 16 cu.ft.

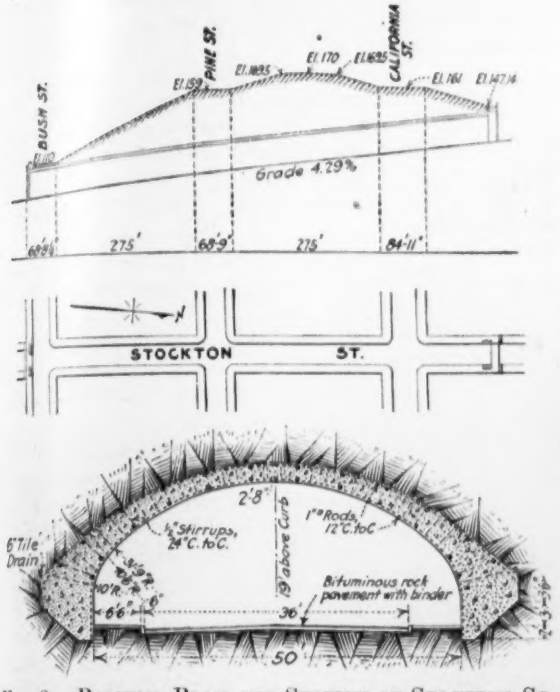


FIG. 2. PROFILE, PLAN AND SECTION OF STOCKTON ST. TUNNEL

could be mixed and placed in one minute. A rate of 40 batches per hour or about 190 cu.yd. per 8-hr. day was a fair average for a steady run.

The Twin Peaks Tunnel

On Nov. 2, 1914, a contract for the construction of Twin Peaks Tunnel was awarded to Robert Storrie & Co., for the estimated sum of $3,372,000. The bore will be 12,000 ft. in length and, after its completion in three years, will open for settlement one of the most desirable residential districts within the city—territory which has remained long undeveloped because of inadequate street-railway facilities. High-speed trains can traverse the tunnel in 6 min., thus reducing from 1 hr. to 15 min. the time necessary to reach the districts beyond the Twin Peaks ridge from Market and Kearny St.

On account of the increasing traffic congestion on Market St., San Francisco's principal commercial artery, it is generally conceded that the time is not far distant when a rapid-transit subway will be necessary under this thoroughfare. With this fact well established, the elevation, location and design of the easterly portion of the Twin Peaks Tunnel were so arranged as to permit the continuation of the tunnel as a subway under Market St. For the present the tunnel cars will connect directly with the surface tracks in Market St. at Castro and 17th St. by means of a suitably constructed incline.

Immediately west of the easterly portal, a large underground station has been provided, to be known as "Eureka Station." This will ultimately be a transfer point where surface passengers may transfer to subway cars, or where passengers from a future Mission Tunnel (from Golden Gate Park) may transfer to subway cars and *vice versa*. Only the essential parts of the station will be built on initial construction. A steel-beam structure was adopted for this section since it affords better opportunities for future extensions. Platforms, 300 ft. in length to accommodate four-car trains, connect at either end with stairways leading to the surface, where they terminate in artistic kiosks with red-tiled roofs and rough-plastered walls.

Considerations of grade, headroom and alignment require modifications in the grade of Castro St. between 16th and 17th St. and a shifting of a portion of 17th St. near Market. This latter requirement necessitated the purchase of a triangular parcel of land at the northwest corner of 17th and Castro St.

FIG. 3. LOOKING UP STOCKTON ST. FROM SOUTH PORTAL OF TUNNEL

The matter of tunnel alignment gave rise to two factions. One advocated a route along a straight line between the two portals and the other advocated a location following under easy surface grades to the intersection of 18th and Hattie St., and thence in a straight line to the westerly portal. The latter alternative was adopted, and a strip of land, 1956 ft. long averaging 90 ft. in width, through the property traversed will be acquired in fee simple, thus providing a tunnel right-of-way and a surface strip of land for a contour extension of Market St. to the crest of Corbett Road, impossible under the first scheme.

Commencing at the easterly portal, the tunnel will ascend a 3% grade for a distance of 9000 ft. to a summit elevation of 436 ft., the gradient being compensated for curvature by reduction to 2.8% on such portions. At the termination of this 3% grade, which is the maximum for the tunnel, a second station will be constructed, to be known as "Laguna Honda." The floor of the tunnel will be 62 ft. below the ground surface at this point; from here the line will descend on a grade of 1.15% for a distance of 3000 ft. to the westerly portal.

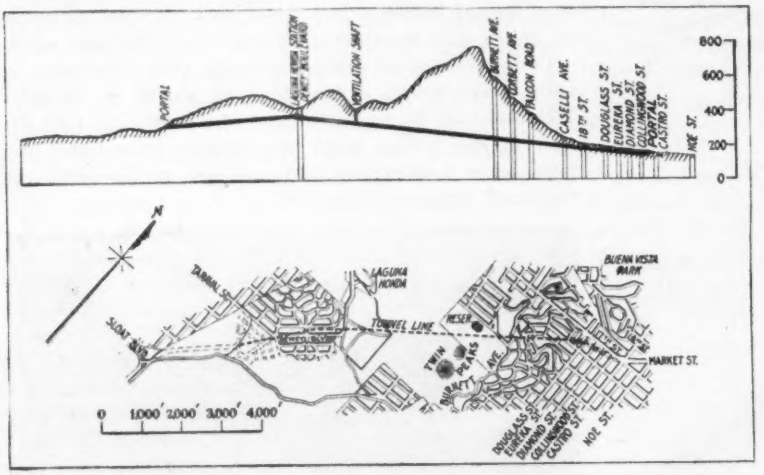
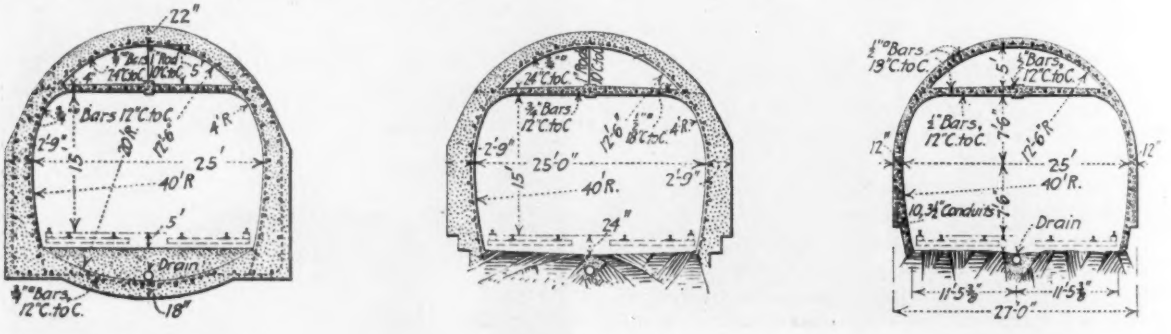


FIG. 1. PLAN AND PROFILE; TWIN PEAKS TUNNEL

Two important factors influenced the selection of the rate of grade from the easterly portal to the Laguna Honda Station; first, the desirability of a station at the location adopted for Laguna Honda, and, secondly, the necessity of operating the trains at high rates of speed. The second consideration limited the maximum gradient to 3%, while the first required the use of this maximum in order that the tunnel might be brought within a reasonable distance of the surface at the point selected for the station.

On the surface, and directly above the Laguna Honda Station in the tunnel, will be erected a reinforced-concrete building about 100 ft. in length, designed after the Mission style of architecture and provided with modern conveniences. Passengers entering the station may reach the tunnel by means of six elevators—located three at each side of the two lobbies. In case of a possible disability of the machinery, they may use the broad central stairway descending 62 ft. to the platforms below. An escalator system will also be installed. The platforms will be 300 ft. long, as at Eureka Station, and centrally located with respect to the escalators and stairways. There will be two platforms, each 10 ft. wide, one for eastbound and one for westbound traffic. On account of the ample headroom available, an arched roof will be used with a span of 44 ft. The elevators will have a capacity of 50 persons each and will consume about half a minute in making the trip from the surface to the tunnel level.

In order to ascertain the character of the material through which the tunnel is to be constructed, borings were made along the route at intervals of from 300 to



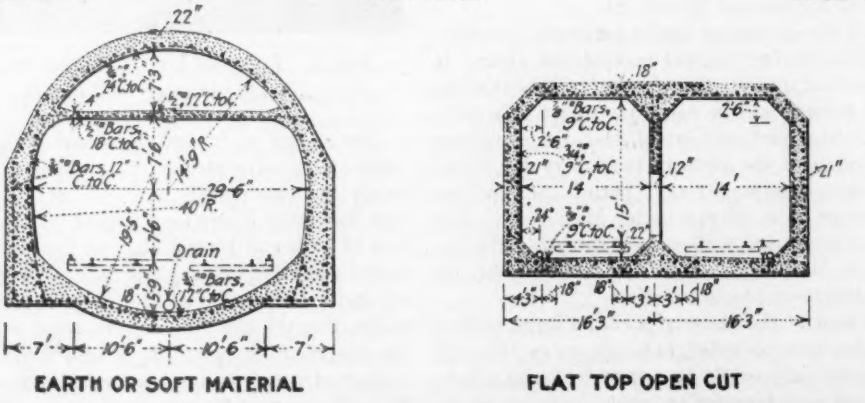


FIG. 2. SECTIONS FOR DIFFERENT FORMATIONS ALONG THE TWIN PEAKS TUNNEL

400 ft. These borings indicate that sand and incipient sandstone will be encountered for a distance of 5000 ft. on the westerly end, passing thence into hard Franciscan sandstone for a distance of 4500 ft. and emerging therefrom into a red sandy clay for the remaining 2500 ft. to the easterly portal.

The inside dimensions adopted for the tunnel proper are 25-ft. width and 18-ft. height. As the borings indicated the presence of considerable water, the arch curve was made semicircular. The sides are slightly curved and the construction of an inverted arch in the bottom is provided for, in case it is found necessary to resist hydrostatic pressure.

Owing to the fact that the difference between the grades of overlying streets and track would not permit the use of an arched tunnel section, it was found necessary to provide a flat-top or "subway" section from 18th and Hattie St. to Eureka Station, and thence to the easterly portal. For this subway a double compartment with a slab top has been designed. The greater length will be built on curves and this will cause the ends and centers of cars to overhang the rails more than on straight track. On account of this, a lateral clearance of 14 ft. will be required. The overhead clearance of 15 ft. remains the same as in the arched tunnel. This section will be built through wet clay, making a slab base imperative in order to provide a stable foundation.

Throughout the length of the tunnel, the contractor is given the option of using brick or concrete in the upper portion of the arch ring. To relieve the water pressure, weep-holes have been provided at intervals of 25 ft. along the length of the tunnel. Through these, water will find its way and be carried off by means of a vitrified pipe, laid in the center of the tunnel and covered by broken-rock ballast supporting the ties and rails of the tracks.

Throughout the entire tunnel, a 12% mixture of hydrated lime will be added to the concrete, which, together with a rich mixture of cement and sand applied with a cement gun, it is believed, will afford sufficient waterproofing for the tunnel and subway sections. About Eureka Station, where leaks and water stains would be more offensive, three-ply felt waterproofing is to be laid on the top and sides of the structure and covered with porous book tile, through which water will percolate and be drained off through the interior holes to weep-holes at the base of the station.

The important matter of ventilation has been given much attention, and the plans call for the construction of a circular vent shaft near the Relief Home, capped on the surface by a head house or air intake of attractive design. In this shaft and at 18th and Hattie St. will be electrically driven blowers, drawing fresh air from the atmosphere and forcing it through a duct formed between the upper portion of the tunnel arch and a suspended concrete-slab ceiling. From here it will be allowed to escape at intervals through dampers into the tunnel proper and thence to the surface at the portals and stations.

In the lining of each tunnel wall will be placed eleven fiber ducts for the accommodation of cables and wires transmitting the electric current for the operation of the trains and for lighting the tunnel and stations.

At intervals of 50 ft., alternating on opposite sides of the tunnel, safety niches will be constructed in the walls and in each will be placed an incandescent lamp. These niches will serve as refuge bays for track walkers and in some of them access may be had to the ducts carrying the power wires.

The present plans do not call for the installation of track, this feature being left for future consideration. Should the municipality decide to engage in further railroad construction these may be installed by the city and rental charged for their use, else a franchise may be granted to some railway company on proper terms. Under the provisions of the city charter, however, such a franchise cannot be exclusive.

The estimated cost of the construction of the tunnel, including the purchase of lands for rights-of-way and other incidental expenses, is $3,994,289. Of this amount, $3,398,973 will be contributed by that portion of the assessment district lying west of Twin Peaks, containing an area of 4153 acres, and $595,316 will be contributed by that portion east of Twin Peaks, containing an area of 660 acres. The average assessment is on the basis of 2c. per sq.ft. ($50 for a lot 25x100 ft.). The maximum is 3½c. per sq.ft. and the minimum ½c. per sq.ft. The assessment will be payable, at the option of the property owners: (1) All at one time; (2) in ten annual installments with interest on deferred payments at the rate of 7%; (3) one-tenth when the assessment becomes due, or as much more as the property owners elect, and the balance in ten annual installments; or (4) the full amount prior to maturity.

Construction Statistics, San Francisco

A great amount of money has been spent in San Francisco during the past ten years, and more is now being spent, on improvements whose cost is approximately as follows:

New sewer system, nearly complete	$6,150,000
High-pressure fire system	5,750,000
Municipal street railways	5,500,000
Asphalt plant	60,000
Civic center	8,800,000
Schools	7,500,000
Hospitals	3,000,000
Fire and police stations	510,000
Public library lands	740,000
Hall of Justice and county jail	1,350,000
Hetch Hetchy water-supply—lands and preliminary work	2,000,000
Docks	9,000,000
Streets and pavements	15,000,000
New parks and public playgrounds	1,360,000
Traffic tunnels	4,600,000
Total	$71,320,000

In addition to the above municipal enterprises, about $11,000,000 has been expended on the Panama-Pacific International Exposition, total expenditures on which will come to about $18,000,000. $7,500,000 was subscribed by corporations and individual citizens of San Francisco and $5,000,000 was raised by the issue of municipal bonds. The total amount of municipal bonds sold during the past ten years is $47,701,200. The City's bonds have generally commanded premiums, so that the total amount of money realized was about $49,253,000. The total amount authorized by the voters but not yet sold is $45,832,800, which includes $43,428,000 for the Hetch Hetchy Water Supply. The harbor bonds are a state issue to which the citizens of the state contribute nothing, as the interest and sinking fund payments come from the port revenues. The difference between the total cost of improvements given above and the total amount of bonds sold is accounted for by premiums on bonds and by payments for work out of current revenues and by assessment districts.

The Municipal Asphalt Plant

A municipal asphalt plant of a capacity of 180 loads or 320 cu.yd. of bituminous wearing surface per day has recently been constructed by San Francisco. The structure is located at Treat Ave. and Florida St.

All material is brought to the plant on railway cars, no teaming being necessary. The sand, rock or gravel is dumped from the cars into a concrete receiving hopper of a capacity of four car loads or 200 tons, from which it is hoisted to a screen and segregated into the proper bin.

The elevator has a capacity of 85 tons per hour, and the screen is 48 in. in diameter by 22 ft. long, with an adjustable jacket. All lime dust is unloaded from the car into a storage room, whence it can be taken as needed.

As designed, the storage bins for the rock and sand are of reinforced concrete, 12 in number, 12 ft. square and 24 ft. deep, and they have a combined capacity of 1536 cu.yd. Under the storage bins are two belt conveyors with a capacity of 36 tons per hour, and the material is fed from the bins upon the belt conveyors by special measuring gates.

These gates can be opened or closed by a shaft gear directly over the belt, which in turn is operated by the belt conveyor. On the shafts are fitted eccentrics which operate a lever and by means of a pawl and ratchet the gate is revolved. Each gate has a range in capacity of from 2 to 12 cu.ft. per minute, and any mixture of fine or coarse rock or sand can be sent to the driers.

The material when taken from the belts is hoisted by an elevator and discharged into the uptakes of the driers. These uptakes are fitted with baffle-plates over which the material slides, coming in contact with and being partially heated by the escaping gases before entering the revolving drying drum.

The drying cylinder is designed with an inclination of 1 on 12. Its shell is ⅜ in. thick, 5 ft. in diameter and 12 ft. long, fitted internally with eight 6-in. channels with their flanges turned in the direction of rotation. The material is carried up and dropped through the flame, gradually working its way toward the lower end. Each drier is fitted with a firing hood on wheels, similar to that used for an ordinary cement roaster.

Below the firing hood are two flight conveyors with a capacity of 36 tons per hour and designed for hot material. These flight conveyors discharge to elevators of the same capacity, which in turn empty into the small storage bins for hot materials ready for the mixer.

The lime dust is conveyed from the storage room to the hot bins by a flat-belt conveyor fitted with oak strips. The dust is emptied directly upon the belt through a hopper, and all the free dust is drawn through a fan discharging into a centrifugal separator, from which it falls back upon the belt.

The hot bins and mixing platforms are of reinforced concrete, and the drier shed is of steel and corrugated iron. Under the hot bins are special measuring boxes for sand, rock and dust. These consist of revolving cylinders open on one side. When the opening in any cylinder is opposite the bin, material drops in, and when the cylinder revolves again until the opening is underneath, the material drops out into a hopper. The rock and sand cylinders have a capacity of 3 cu.ft. per dump.

Asphalt is fed to the mixers in a liquid state and is measured in horizontal cylinders, each having an internal piston worked by a screw and handwheel. By changing the position of the piston, the amount of asphalt used can be controlled. Each cylinder is steam-jacketed, and is fitted with a thermometer so that the attendant can easily read the temperature of the liquid before injecting it into the mixer. Asphalt is forced from the measuring cylinder into the mixer by means of compressed air.

The mixers are 4 ft. 8 in. long by 3 ft. 5 in. wide, with a capacity of 12 cu.ft. per mix. The shafts are 3 in. square and are fitted with 12 sets of semisteel paddles on each shaft. The shell is ¼-in. steel plate, and the heads are of cast iron. While the mixer works on one batch the next batch will be prepared in the hopper directly above. One man can perform all of the operations for each mixer.

A 60-hp. boiler with superheater furnishes steam for heating the asphalt in the tanks, each tank having forty-eight 20-ft. lengths of 1½-in. pipe with all joints welded. The temperature of the asphalt is controlled by a thermostat operating a valve on the steam line. The asphalt runs from the car by gravity into the concrete tanks and is pumped from the tanks to the mixers by a 2½-in. gear pump.

An oil-burning system for the boilers is operated with

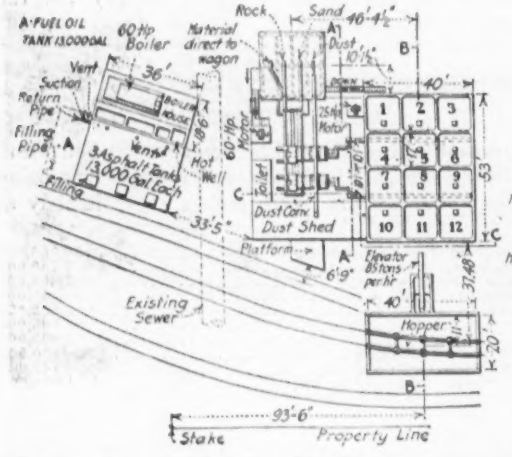


Fig. 1. Plan of the New Municipal Asphalt Plant, San Francisco, Calif.

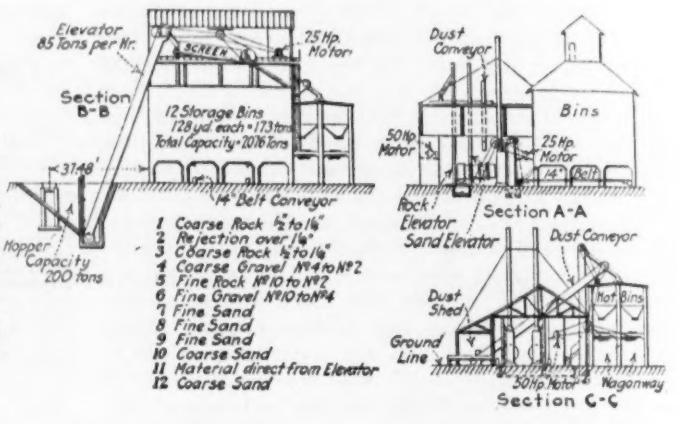


Fig. 2. Sections of New Municipal Asphalt Plant, San Francisco, Calif.

compressed air, which is used for blowing out the asphalt pipes when closing down. The plant is equipped with a large centrifugal pump for pumping out any of the elevator pits, should water collect.

All machinery will be driven by alternating-current motors, one 25-hp. motor being used to operate the main elevator and screen, one 50-hp. motor to operate the belt conveyors, elevators and driers, one 25-hp. motor to operate the flight conveyors' elevators and mixers. The air

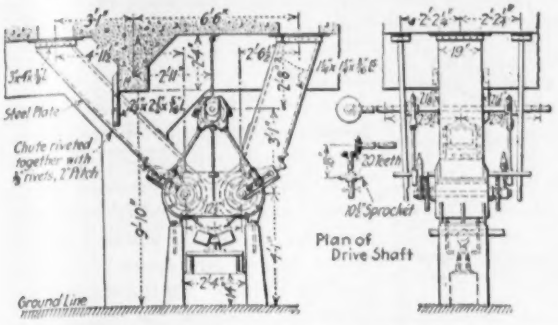


Fig. 3. Measuring Device for Aggregates, San Francisco Municipal Asphalt Plant

compressor is operated by a 10-hp. slip-ring motor, automatically controlled.

The machinery, materials and workmanship are the best obtainable, extra care having been taken in the design to eliminate, so far as possible, the wear of the machinery by the sand, rock and dust and to decrease the maintenance costs.

To operate the entire plant nine men are required, one for the receiving hopper, one in the screen house, one for the driers, two for the mixers, one for the boiler house, one for the dust shed, one to tend asphalt and dust cars and one superintendent.

The buildings and equipment were designed under the direction of the City Engineer's office.

Mission Street Viaduct

The oldest thoroughfare in San Francisco is the Mission Road, which extends south from the city and passes through the larger suburbs on the peninsula. Although the route was chosen over a century ago by a few scattered settlers, it was well selected. However, the channel of Islais Creek, which is crossed at right angles, necessitated long grades in places as steep as 12%, which were subsequently the cause of many serious street-car accidents. In 1911, to improve this main artery of vehicle and street-railway traffic, the Board of Supervisors appropriated from the general taxes the sum of $216,000, with which to construct a high reinforced-concrete viaduct over Islais Creek, and decrease the approaching grades to a maximum of 4%.

At the viaduct the width of the roadway is 58 ft. 6 in., exclusive of the 12-ft. sidewalks on either side (Fig. 2). The center is occupied by the double tracks of an electric street railway, and used for local and interurban traffic. The north approach, 360 ft. in length, and the northern portion of the viaduct itself, for a length of 480 ft., are constructed on a 4% grade. The remainder of the structure is level, as is the south approach for a distance of 67 ft. beyond which the grade changes to 3.38% for a distance of 660 ft. The approaches consist of earth embankments, well compacted, with a side batter of 1 on 2. Over 6000 cu.yd. of fill were required for the north approach, and for the south embankment over 20,000 cu.yd.

The sides of the viaduct, 58 ft. 6 in. apart, are designed as retaining-walls, 3 ft. 6 in. in thickness at the base and 1 ft. 4 in. at the top, varying in height from 15 to 32 ft. The outer surfaces of the two walls are indented in arched sections as shown on Fig. 1. Concrete pilasters 4 ft. wide and spaced at 24-ft. centers support these arches. The sidewalls are tied together by reinforced-concrete cross- or tie-walls 12 in. thick, so that the entire structure is divided into compartments 58 ft. 6 in. by 23 ft. inside dimensions, except where the tracks of the Ocean Shore R.R. are crossed by a 137-ft. opening made up of four spans and where Springdale St. is crossed by a 60-ft. span.

Outside the outer reinforcement at each pilaster a 78-lb. rail embedded in the concrete forms a bulb beam around which the horizontal reinforcement of the transverse tie-walls is bent to strengthen the tie between the sidewalls.

Where Springdale St. passes under the viaduct at right angles, and where the Ocean Shore R.R. tracks cross at

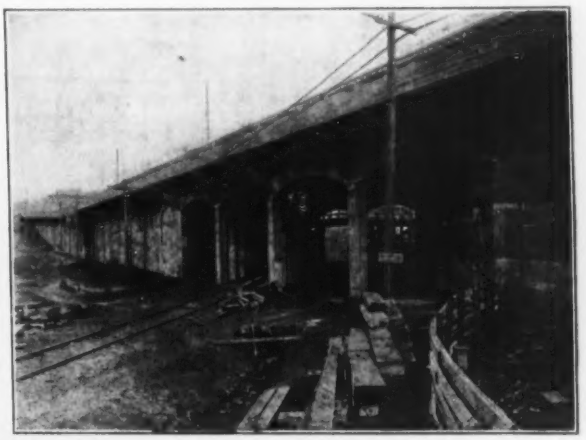


Fig. 1. The Mission St. Viaduct at the Ocean Shore R.R. Crossing

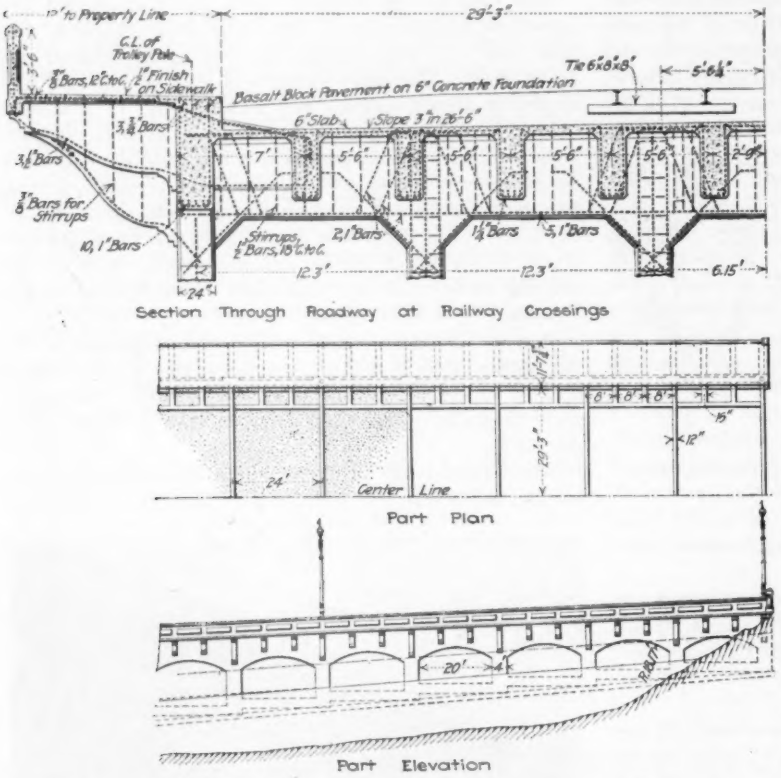
an angle of 31° 46′ heavily buttressed transverse retaining-walls act as end walls for the compartments.

A four-section girder-and-beam span crosses the tracks of the Ocean Shore. There are three transverse girders, each supported by nine columns. The end columns are 2x3 ft. in section and the seven intermediate columns under each beam are 22 in. square, all supported on slab bases 6 ft. 8 in. square and 2½ ft. thick. Each slab rests upon a cluster of five reinforced-concrete piles driven to bedrock. Between the transverse retaining-walls and extending over the transverse girders are the longitudinal beams that support the floor system above the spans. These beams are spaced at 5-ft. 6-in. centers, are 18 in. wide, 4 ft. deep, and heavily reinforced with 1-in. and 1¼-in. continuous bars and shear bars. Sidewalls are carried over the spans by arch beams that support the sidewalk (Fig. 1).

Reinforced-concrete piles carry both side and end retaining-walls as well as the slab foundations for all columns.

Twelve-foot sidewalks project over the longitudinal walls and are supported by ornamental concrete brackets 16 in. wide at 8-ft. centers.

All the compartments heretofore described are filled with sand thoroughly water-tamped. In all, 40,000 cu. yd. of fill were deposited in the structure.



FIGS. 2-3. PLAN, ELEVATION AND SECTION THROUGH ROADWAY, MISSION ST. VIADUCT

CONSTRUCTION

To accommodate street-car and vehicle traffic while the viaduct was in course of construction it was necessary to erect a temporary trestle 1000 ft. in length and 28 ft. wide, immediately adjoining. The reinforced-concrete piles, 788 in number, composed of a 1:2:4 mixture, were molded on the site in various lengths, allowed to set for 45 days and then driven with a steam hammer on which the 2½-ton plunger fell through a distance of 3 ft. While being driven the piles were protected by a lignum-vitæ buffer and a steel plate clamped rigidly over the head. All were driven until the penetration was less than ½ in. per blow, and scarcely one of the heads was fractured. The material through which they were driven was a tough mixture of sand and clay.

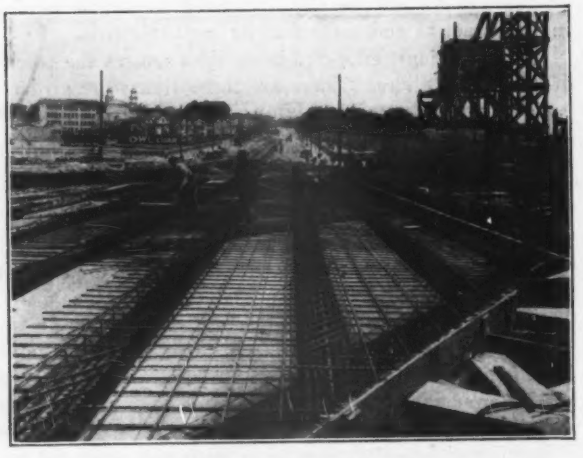


FIG. 4. VIEW OF RAILWAY CROSSING UNDER CONSTRUCTION

Forms of 1x4-in. tongue-and-groove lumber were used wherever the finished concrete surface would be visible. Three 1-yd. mixers were operated on the ground and the mixed concrete raised by skips to towers, where it emptied into a hopper and thence was distributed by a chute. In the sidewalls, tie-walls and footings, the consistency of the concrete was 1 part of cement to 7 of aggregate. For columns, beams, brackets and hand-rail a 1:6 mix was adopted.

When the concrete had set and immediately after the forms were stripped all visible surfaces were plastered with a 1:3½ cement-sand mortar. A track was constructed over the tie-walls and beach sand hauled by the United Railroad Co. in electric dump cars, deposited in the compartments and thoroughly flooded. When this had completely settled the street-railway tracks and the 6-in. concrete base for the roadway pavement were laid. On the concrete base a basalt block surface was constructed with asphaltic cement joints, and the viaduct opened to traffic.

Municipal Street Railways

San Francisco officially declared itself in favor of municipal ownership in 1900 when the electorate adopted a new city charter in which the intention of the city to acquire, own and operate public utilities was expressly stated. After the issuance of a $2,000,000 bond issue was defeated by a narrow margin at an election held in June, 1909, a second election was called for Dec. 29 of the same year, at which two municipal railway bond issues were submitted. One provided for $1,900,000, with which to build an electric line on Geary St., extending from Market St. to the Ocean; the second, amounting to $120,000, was for the construction of a line down Market St., from Geary to the Ferries. Both propositions carried by a three to one majority.

CONSTRUCTION

Construction of the Geary St. railway was started in the summer of 1911 and was completed in June, 1913. The cost of constructing this road was $103,564 per mile of single track and the financial returns on the money expended have been very satisfactory. Encouraged by these results, and realizing that the suc-

cess of the Panama Pacific Exposition depends largely on the adequacy of street-railway transportation facilities to the Exposition grounds, the city officials submitted to the electorate, on Aug. 26, 1913, a proposition providing for the issuance and sale of bonds to the amount of $3,500,000 for the extensions to the municipal street-railway system. The bonds were carried by a vote of 51,649 to 13,720 and the Board of Public Works was directed by the Supervisors to proceed at once with construction.

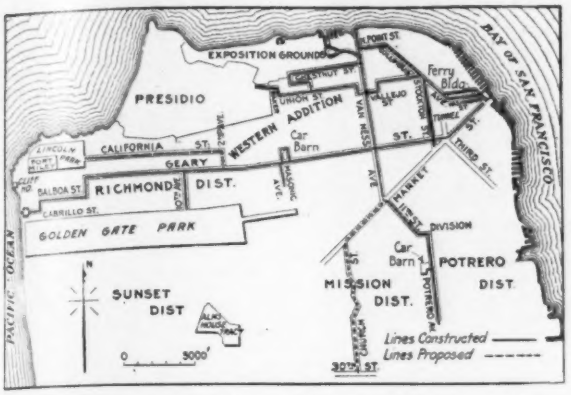


FIG. 1. MAP OF THE SAN FRANCISCO MUNICIPAL RY.

Time was a vital consideration in completing the projected lines, as it was essential that all of them should be in operation before the Exposition opened in February, 1915. The City Engineer forthwith prepared a schedule for the design and construction of each portion of the road and named the dates on which bids would be received. In practically every instance work was completed in less than schedule time. The system of inserting a bonus and penalty clause in all specifications and strictly enforcing the conditions relative to time limitations has proven very effective in securing rapid work.

The type of track construction adopted as a standard for the railway extensions follows almost identically that of the Geary St. line, which has proven most satisfactory. Briefly, this consists of 9-in. 106-lb. girder grooved rail in 60- and 62-ft. lengths, and 9-in. 129-lb. girder guard rail in 30- and 32-ft. lengths. These are laid on tie-plates over 6x8-in.x8-ft. redwood cross-ties, at 2-ft. centers, with $\frac{7}{8}$-in. round tie rods spaced 10 ft. in straight track and 5 ft. in curves. Rails in curves are supported by braced tie-plates. Joint plates are 36-in. 12-bolt standard sections. The depth of broken-rock ballast under the ties is 8 in. in standard track and 15 in. in special work. Copper rail bonds, aggregating 900,000 circ.mils in section, are brazed directly to the rails by means of an electric bonding machine.

All track special work is of solid manganese steel and consists so far as possible of interchangeable switches, mates, frogs and cross-pieces, which in various combinations will compose any layout of branch-offs, cross-overs and right-angle crossings, or combinations thereof, in standard 9-in. track. In the design of these standard pieces, an endeavor was made to reduce the number to a minimum as their interchangeability will facilitate maintenance. The total number of pieces of different design is 35. The section of all joints in track special work is such as to permit the use of the standard joint plates without modification.

Curves have been so designed as to give passing cars clearance of not less than 12 in.

The roadbed for these portions of the municipal lines at present completed has been excellently and rapidly constructed. A 3-in. sharpened circular steel flange attached to the cylindrical surface of a steam roller was used in cutting the asphalt surface of the street pavement. This wearing surface and the concrete base beneath were then broken by a 2-ton drophammer piledriver mounted on skids so as to permit of being swung from side to side of the trench and at the same time moved forward as the pavement was broken up. The broken concrete base was next removed from the trench and fed to a movable crusher which reduced it to ballast size. The roadbed was then excavated to subgrade, by means of a half-yard steam shovel. Six inches of the crushed concrete was then spread on the subgrade and flushed with sand, after which the surface was rolled with a 10-ton steam road roller.

Ties were next laid, the rails placed on the tie-plates, the joints bolted temporarily and the rails spiked to gage. A maximum variation of $\frac{1}{16}$ in. was permitted from the standard of 4 ft. 8½ in. Straight rails and track special work were hauled to the job by four-horse trucks, and ties and smaller materials by auto truck. All rail bending to horizontal and vertical curves was done by the contractor, some in the field by means of a hydraulic rail bender operated by a hand pump, and some by power machines at the rolling mills or railroad shops.

After the rails were spiked, the track was raised to grade and 2 in. of ballast tamped under the ties. The joint-plates were removed, the rails bonded, the joint-plates replaced and fastened permanently, and the tie-rods put in place. Such drilling and reaming as were necessary were done with a portable electric track drill. The aligning and surfacing gang then adjusted the track to perfect line, gage and grade. The space between the ties was next filled with ballast, the concrete base for header blocks and pavement poured and the pavement replaced.

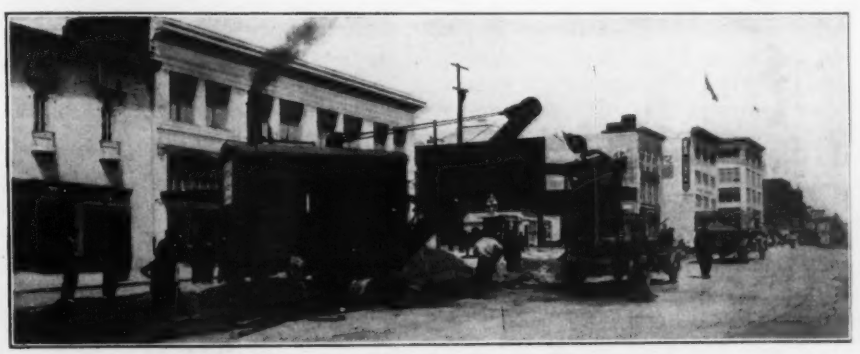


FIG. 2. EXCAVATING FOR TRACKS ON VAN NESS AVE.

One hundred and twenty-five new cars, costing $7200 each, have been purchased for the Municipal Railway. They are of what is called the California semisteel type, 47 ft. 1 in. long over bumpers, 9 ft. 2½ in. wide and 11 ft. 8 in. high from the top of the rail to the top of the trolley board. They are of the same length as the cars now in use on the Geary St. line, but of greater width and will accommodate more passengers. Being of improved structural design they are lighter in weight, which tends toward reduction of maintenance costs.

FIG. 3. PREPARING SUBGRADE FOR TRACKS IN VAN NESS AVE.

All of the structural parts of the car, up to the window sills, are of steel and so formed as to give extreme rigidity with a minimum of weight. The construction above the window-sill line is of the finest grade of California wood. The roof is notable in that no inner lining is provided, the roof boards being of white cedar, which was purchased in San Francisco by the car builders and shipped east to the factory. This wood was selected for grain and color and has been varnished, presenting a very pleasing appearance and at the same time reducing the weight of the roof structure without sacrificing anything in the way of strength.

The motor equipment consits of four box-frame 60-hp., 600-volt inclosed interpole motors with multiple-unit-switch control. This apparatus was made by the Westinghouse company. The cars can rapidly be brought to full speed and have sufficient power to surmount heavy grades at a normal speed. The motor equipment enables the cars to outclass those of the private corporation by 3 min. in the trip from Market St. to the Cliff House.

The air-brake equipment (straight-air type) has special additional features as emergency safety devices. A valve is installed under the car which will automatically set the brakes in the event of any of the air-brake pipes or appurtenances being disabled. At each end of the car, within reach of the conductor, is an additional emergency air valve.

For housing the municipal cars, two reinforced-concrete barns have been provided. One is located at Geary St. and Presidio Ave., the other on Hampshire St. at 17th.

The overall outside dimensions of the Geary St. barn are 275 and 343 ft. It is capable of accommodating 134 cars. The Hampshire St. barn is 200x382 ft. overall, with two stories, each capable of accommodating 90 cars. A distinctive feature of this structure is in the fact that both floors are provided with repair pits for the entire length of the trackage. A complete fire-protection sprinkler system has been installed, and a vacuum system [illegible] cleaning the cars.

OPERATION

Despite the predictions of opponents of municipal ownership that the railways the city proposed to build could not be operated on a paying basis alongside the privately controlled lines, during the first two years of operation the municipal-railway system has proven an excellent investment. The income has been sufficient to defray operating expenses and depreciation costs, to provide a sinking fund for the bonds, and to pay for needed extensions to the system, as well as purchase the physical structures and equipment of a heretofore privately operated street railway.

The keynote of this success has been the elimination of politics and the adherence to strict business principles in the management of the roads. Before organizing the operating force, the Mayor requested the Chairman of the Public Utilities Committee of the Board of Supervisors to investigate the qualifications of men available for the position of Superintendent and recommend the most suitable candidate. The Chairman of the Public Utilities Committee recommended a man personally unknown to any of the city officials, except by reputation. His selection was decided solely on the recommendations of street-railway officials whose judgment could be relied on. The Assistant Superintendent and Master Mechanic were appointed on the recommendation of the Superintendent who selected them on a strictly merit basis. All other employees were appointed from a civil-service list in their order of standing so that the operation of the road is absolutely unhampered by politics.

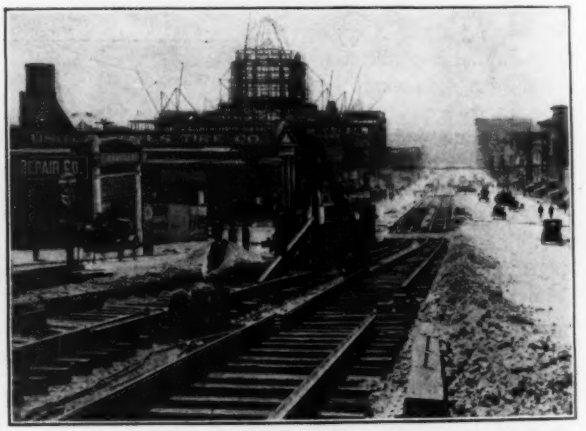


FIG. 4. TRACK LAYING FOR MUNICIPAL RY.

Requirements of the Interstate Commerce Commission were strictly adhered to in adopting a system of accounts for the municipal lines. For the fiscal year ending June 30, 1914, the results of the Geary St. division were as follows:

Gross receipts		$642,450.74
Total operating expenses		294,036.22
Excess of receipts over expenditures		$348,414.52
Liability compensation	$3,886.83	
Depreciation and renewals	115,641.13	
Interest on bonds	88,605.00	
Municipal franchise	19,224.31	
Municipal car license	645.00	
State franchise	30,516.41	
Federal income tax	1,402.81	
Legal and clerical service	3,600.00	$263,521.49
Leaving a net profit of		$84,893.03

The financial results of the operation of the Union St. road from Dec. 11, 1913, when it was taken over by the city, to June 30, 1914, are as follows:

Gross receipts		$189,536.09
Operating expenses		100,931.58
Balance		$88,604.51
Interest paid to Ferries & Presidio R.R. Co.	$3,740.25	
Liability compensation	2,537.14	
Depreciation and renewals	3,740.14	
Interest on bonds	34,116.50	
Municipal franchise tax	5,675.31	
Municipal car license	240.38	
State franchise	9,002.96	
Federal income tax	405.96	
Legal and clerical service	900.00	$64,232.84
Leaving a net profit of		$24,371.67

OPERATION OF GEARY STREET MUNICIPAL RAILWAY

Month	Days	Receipts	Per Day	Operating Expenses	New Earnings Per Mo.	New Earnings Per Day
1912—						
Dec.	4	$3,300.60	$825.15	$1,076.78	$2,223.82	$555.95
1913—						
Jan.	31	17,465.35	563.40	9,835.90	7,629.45	249.34
Feb.	28	18,619.90	665.00	10,461.92	8,157.98	291.35
Mar.	31	22,023.20	710.42	12,806.46	9,216.74	297.31
Apr.	30	22,034.65	734.49	11,648.81	10,385.84	346.19
May	31	23,525.25	758.88	13,338.10	10,187.15	328.61
June	30	27,955.00	931.83	14,083.35	13,871.65	462.39
July	31	46,836.50	1,510.85	19,952.82	26,883.68	867.21
Aug.	31	50,600.65	1,632.28	21,779.84	28,820.81	929.70
Sept.	30	52,508.65	1,750.29	21,575.48	30,933.17	1,031.10
Oct.	31	58,693.05	1,893.32	23,923.79	34,769.26	1,121.59
Nov.	30	49,279.60	1,642.65	23,702.76	25,576.84	852.56
Dec.	31	51,823.85	1,671.74	25,750.62	26,073.23	841.07
1914—						
Jan.	31	53,644.15	1,730.47	25,134.04	28,510.41	919.69
Feb.	28	50,958.23	1,819.94	24,152.19	26,806.04	957.36
Mar.	31	57,427.95	1,852.51	27,472.17	29,955.78	966.31
Apr.	30	55,442.51	1,848.08	26,557.52	28,884.99	926.83
May	31	56,991.62	1,838.44	28,631.74	28,359.88	914.83
June	30	53,958.28	1,798.61	28,415.02	25,543.26	851.44
July	31	99,031.58	3,194.56	40,396.68	58,634.90	1,891.45
Aug.	31	98,691.10	3,186.16	51,445.18	47,245.92	1,524.06

Note: Figures since July, 1914, include entire Municipal System; separate revenue receipts for each line available, but no segregation made of operating expenses.

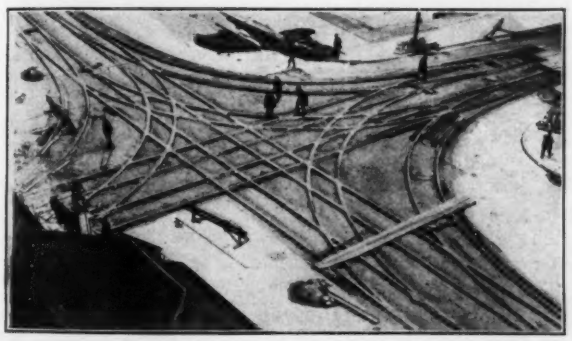


FIG. 5. THREE-QUARTER GRAND JUNCTION; VAN NESS AVE. AND GEARY ST.

The service on the Geary St. road is admitted to be the most satisfactory in the city. Between the Ferry and Van Ness Ave., cars are operated on a headway of 1 min. 12 sec. during the rush hour, and from Van Ness to the Beach on a headway of 1 min. 32 sec. Many residents in the district toward the westerly end of the road habitually walk across the tracks of the privately owned street railroads to Geary St. in order to patronize the municipal cars, stating that the time saved in reaching the business district more than repays the additional effort required. On the Union St. road, the service has been considerably improved, especially on that portion between Van Ness Ave. and Steiner St., since the city undertook its operation. The cars, however, are old and the grades are steep and objectionable; the authorities contemplate replacing the cars with new stock of a more modern type at the earliest possible moment. The support which has been given to the municipal roads by the traveling public has been highly gratifying and indicates a high appreciation by the citizens of San Francisco of the efforts of the railway officials to furnish adequate service.

FIG. 6. ONE OF THE NEW CARS OF THE MUNICIPAL RY.

In constructing the municipal system, the City Engineer decides all matters of policy and design. His position is analogous to General Manager of a privately owned system. The Consulting Mechanical Engineer is responsible for the preparation of plans and specifications, apportionment of finances and all work preliminary to purchasing material and awarding contracts. The Chief Assistant City Engineer has charge of the construction of the lines and the payment to contractor of the progress installments for the work. Frequent conferences be-

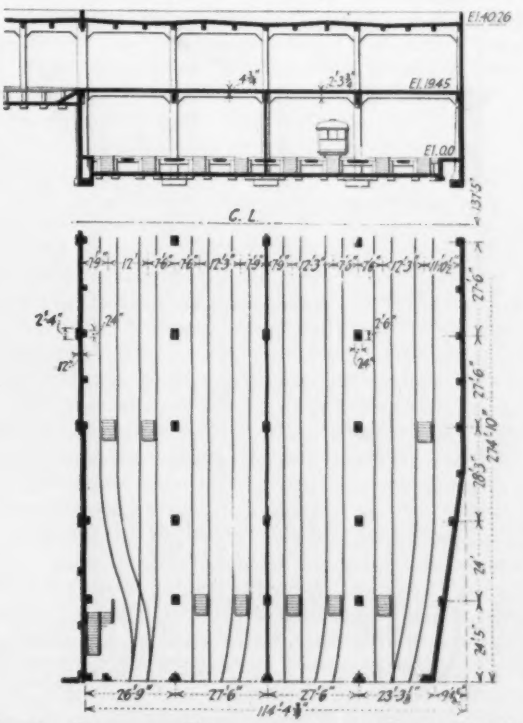


FIG. 7. PLAN AND ELEVATION OF THE GEARY ST. CAR BARN

tween these three officials and the Superintendent tend to a coördination of the construction and operating departments.

That street railways can be built and operated by a municipality in an efficient manner and without being made the plaything of politicians has been abundantly proven in San Francisco. Continued freedom from political interference will, of course, depend largely upon the vigilance of the people. The friends of municipal ownership see reasons to hope that this vigilance will continue to be exercised, first in the fact that a large part of the public comes into daily contact with the street railways and will immediately notice any evidence of mismanagement and, secondly, in the evidence which is already apparent that the citizens of San Francisco are immensely proud of their municipal railroads and firmly determined to make them a continuing success. Of course, it cannot be maintained that the city, which under its charter is required to pay its platform men not less than 37½c. per hr. as against 30c. paid by the United Railroads, can operate a street railway as cheaply as can a private corporation. On the other hand, no private corporation can secure the money necessary to construct street railways nearly so cheaply as can the city. In this connection, it is interesting to note that, while the 48 miles of single-track street railroad which the city will own, when the roads now under construction are finished, will have cost, with their equipment, approximately $110,000 per mile of track, the United Railroads are capitalized for approximately $350,000 per mile of track.

While the discussion of the wisdom of the city engaging in the construction and operation of street railways has been confined almost entirely to the question of whether such operation will or will not pay a profit into the City Treasury, there is a larger and far more important question involved. That is the effect which the construction of the street railways may have upon the health and happiness of the citizens. Viewed in the narrow light of possible profits there is room for speculation as to the wisdom of municipal ownership but when consideration is given to the possibilities of developing the city, opening up the outlying districts for residential purposes so as to provide healthful and attractive habitations for the people, there can be little question of the advisability of the city's engaging in this sort of enterprise.

Anyone who will spend half a day on the outskirts of any city of considerable size, will be impressed with the remarkable effect which street railways may have on [illegible] distribution of population. No private company, [illegible] it owns large areas of land in the vicinity (as did [illegible] Realty Syndicate when it undertook the development [illegible] the suburbs of Oakland), can afford to construct [illegible] railways for any considerable distance into uninhabited

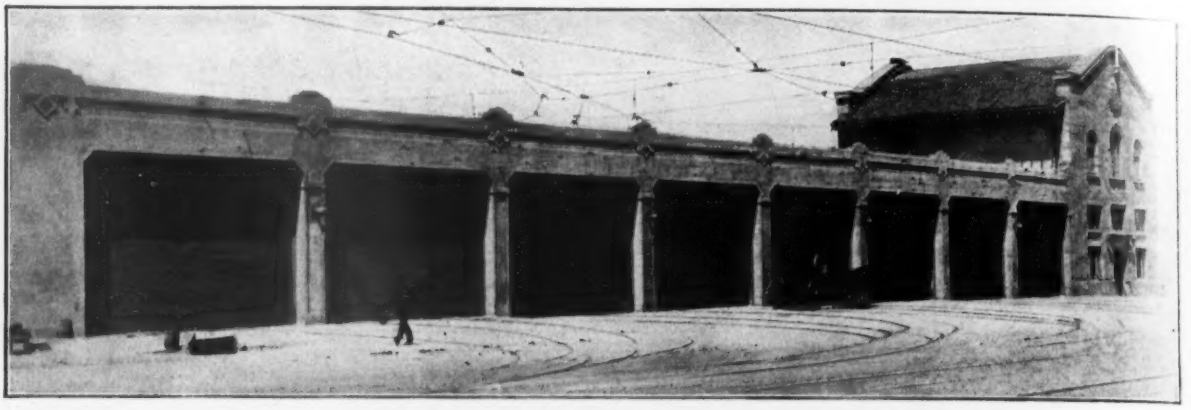


FIG. 8. THE GEARY ST. MUNICIPAL CAR BARN

districts, for the very simple reason that such railroads cannot be expected to pay even their operating expenses, much less a profit, for a great many years. A city, however, is in a different position, for the construction of a street railway, provided reasonable judgment is used in its location, results in an immediate increase in the value of property adjacent to it and a consequent increase in the taxes paid into the city treasury by the property owners—to say nothing of the intangible but none the less important advantages of better housing conditions and increased population. Long before the street railway could pay a profit, the money paid into the treasury in the form of taxes more than offsets the money paid out in the form of operating expenses.

The manner in which the construction of such development roads should be financed is worthy of serious consideration. It seems not unreasonable that the owners of real estate affected should pay over at least a part of the enhanced value of their lands since they reap the more immediate profits from the enterprise. The question, however, is too big to be more than suggested in such a paper as this.

The 48 miles of railway which San Francisco now owns or is constructing were located with a view to their utilization as the nucleus for a comprehensive system which may be eventually extended into the outlying districts—without terminals in the retail and business districts, which would be of little if any use to anyone. It is the hope of the authorities to extend these roads, in the near future, into uninhabitated sections of the city for the purposes suggested.

The "Jitney" Bus Industry, which was introduced into San Francisco about Dec. 1, 1914, is becoming quite a factor in the way of city transportation. Already it has made its presence felt by the street car companies and promises to develop into a competitor in the near future. One factor which will be a benefit to San Francisco will be the increased transportation facilities which these buses will furnish to the Panama-Pacific Exposition grounds. The fare charged is the same as on the local street cars and the distance over which the passenger can be transported is approximately three miles for a single fare.

Laying a Submerged Sewer Outlet at San Francisco

An unusual method has been adopted for laying the Baker's Beach outfall sewer described on page 307 of this issue. The usual method is to use a barge with an inclined cradle on which separate pipe lengths are connected, calked and lowered as the barge is moved forward. It was decided by the contractor that a more economical way would be to lay this pipe in a straight line just above high-tide mark and parallel to the water's edge, pour and calk the joints, seal the two ends, buoy the whole line, float it into its position at right angles to the shore, and then remove the buoys and allow the pipe to settle to its final position.

FIG. 1. MAKING READY TO LAUNCH

FIG. 2. EFFECT OF STORM BEFORE LAUNCHING

(Laying the Baker's Beach Outfall Sewer at San Francisco)

For this purpose (see Fig. 1) 8x8-in. timbers 50 ft. in length, spaced at intervals of 24 ft., were laid at right angles to the water line, to serve as skids. On each skid an 8x8x30-in. cradle runner was placed, the 18-in. ball-and-socket joint pipe laid over these, and the joints poured and calked. The skids extended shoreward from the average high-water mark, the intention being to lay the pipe well above the highest high tide. Due to an existing pipe that terminated half way between mean high tide and extreme high-tide marks, it was impossible, for the first attempt, to lay the pipe as far inland as was desirable to avoid interference from unusually high tides.

When all the joints had been thoroughly calked a "straightback" made up of 6x8-in. timbers, was laid along the top of the pipe and securely attached to it with No. 8 wire. This straightback was securely stiffened where the timbers joined, so that it would hold the pipe in a straight line while it was being floated into place. Sixty-two 12-ft. pipe lengths, or a total of 744 lin.ft., were thus secured.

The weight of each length of pipe was approximately 2400 lb. and its displacement when submerged would be 24 cu.ft. Hence, since the line was sealed, a buoyant force of only 900 lb. per pipe length was necessary to prevent submersion. Four oil barrels each with a capacity of 60 gal., or a displacement submerged of 8 cu.ft., were attached to each pipe, furnishing an additional buoyant force of 2000 lb. per length.

Board covers 30 in. sq. and 2 in. thick were used to seal the ends. Both of these were securely fastened to flange collars around the pipe by four ¾-in. bolts. Between the board cover and the pipe ends, cardboard gaskets were inserted to insure against leakage.

For the reason previously stated, the pipe was first laid close to the mean high-water mark. On the evening of Dec. 30, 1914, when almost all preparations for launching were complete, a severe storm, accompanied by an unusually high tide, moved the pipe from its original position into the curves shown in Fig. 2.

The whole configuration of the beach, which is of loose sand, was changed by this storm. The existing pipe, which had heretofore stood as an obstruction, was covered by some 4 ft. of sand, so that it was possible to straighten the pipe, at the same time moving it back to a safer distance. Due to the flexibility of the joints it was not necessary to remove the lead, but only thoroughly to recalk each joint after the pipe had been straightened.

Preparations for launching the pipe are almost complete, and the result of the experiment will be watched with interest and later reported in ENGINEERING NEWS.

An Acknowledgment to the City Engineering Force

The present City Engineer, M. M. O'Shaughnessy, wishes to pay tribute to the unselfish and conscientious work of Marsden Manson, his predecessor in office, who was identified during a very trying period with the inception of many of the herein described projects; also to Loren E. Hunt, Chief Assistant City Engineer, and T. W. Ransom, Consulting Mechanical Engineer; and to the members of his staff, whose devotion to their duties and the city's welfare the public should remember with gratitude.

Illumination Features of the Panama-Pacific Exposition—The illumination of the Panama-Pacific Exposition will have the unique feature of being almost entirely by indirect light. Over 900 searchlights will be used for this purpose. A battery of 36-in. searchlights will be operated from a replica of Morro Castle built on the outer arm of the yacht harbor. This will be one of the main sources of night light. Several palaces, notably Festival Hall, will have powerful searchlights concealed in pits below floor level; and in the Palace of Horticulture the rays will be thrown through revolving colored screens, each color change requiring 48 sec., producing a constantly shifting opalescent effect upon the glass of the great dome, which is 182½ ft. in height and 152 ft. wide, being the largest hemispherical dome of glass ever constructed.

Other San Francisco Engineering Works

SYNOPSIS—The preceding 37 pages are devoted to those municipal engineering works of the City of San Francisco which are under the direction of the city engineering department. The two other notable San Francisco engineering works described below are under other jurisdiction.

The Improvement of San Francisco's Water Front

By Jerome Newman*

To prepare for an expected increase in maritime commerce resulting from the opening of the Panama Canal, San Francisco has been busily engaged in improving its water front and providing commodious modern docks. The construction includes a modern sea wall, piers and ferry slips, and an extension of the State Belt railroad from the Embarcadero to the grounds of the Panama-Pacific Exposition.

The recently constructed sea wall (Fig. 1) differs from the previously existing structure in that the rock wall is higher and placed at the easterly curb lines of the Embarcadero 60 ft. back of the waterfront line, which gives a greater depth of water at the edge of the bulkhead and, as the concrete retaining wall is located at the crest of the rock embankment, affords the additional advantage of a uniform foundation for the bulkhead pavement. Such a uniform foundation will prevent the unequal settlement that has been observed in some of the bulkheads previously constructed, in which the outer 27 ft. of pavement rests on the concrete slab, and the inner 33 ft. on an earth fill. The new concrete retaining wall, shown in Fig. 1, is carried 13 ft. below City Base, instead of 30 ft. as heretofore, making it possible to deposit all concrete in the dry, instead of partially under water. The bottom rests on wooden piles, cut off at low water, surrounded by rock, and consequently not liable to decay or exposed to the attack of the marine borers. The deck is supported by reinforced-concrete piles 16 in. square, driven through the rock embankment. In order to avoid shattering, the tips were shod with steel.

On account of the mud bottom on which the rock wall rests it was considered advisable to provide for possible future settlement by constructing the deck of the bulkhead wharf of steel beams, carrying a pavement of plank covered with asphalt. If necessary the deck can later be raised, the steel protected with concrete and the planking replaced with a concrete slab.

Before preparing the plans for new piers the question of the most suitable type of construction was thoroughly discussed. It was finally decided that the use of creosoted piling in certain cases would be preferable to the exclusive use of reinforced concrete, which has been adopted where deemed practicable. Factors influencing this decision were: the great depth of mud along certain portions of the water front entailing excessive expenditure for concrete construction on account of the difficulty of providing suitable foundations; the urgent necessity of being immediately prepared for the opening of the Panama Canal; the constant changes in vessels and freight-handling methods and the consequent probability of alterations in the near future to meet new conditions; and last but not least, the uncertainty among engineers regarding the probable life of reinforced concrete under the action of sea water. A commission of engineers appointed by the Maritime Affairs Committee of the Chamber of Commerce to investigate this question concurred in the decision.

Float observations at the northern portion of the front disclosed the existence of a very strong tidal current in this vicinity. As this might endanger wooden pile structures it was decided to build of concrete the three most exposed piers of the seven contemplated for this section, that these might act as breakwaters and deflect the current eastward away from the shore. Therefore Piers 29, 39 and 35 are of reinforced concrete, the first

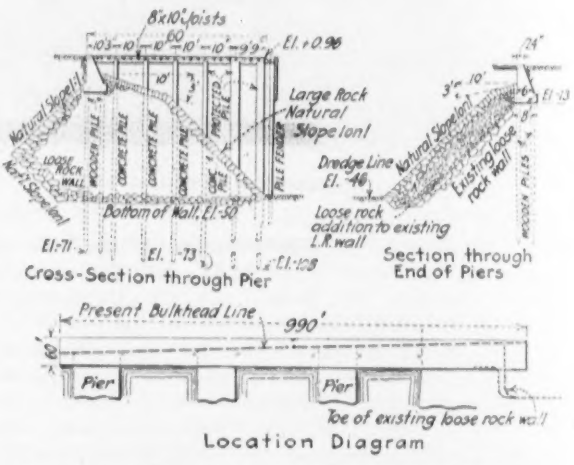


Fig. 1. Details of New San Francisco Sea Wall

two supported by large concrete cylinders and Pier 35 by concrete piles.

Pier 39 (Fig. 3), which is typical of the reinforced-concrete type, is 938 ft. in length and 140 ft. wide. The substructure consists of reinforced-concrete cylinders 3 and 3½ ft. in diameter, carried down from 10 to 14 ft. below the dredge line, and supported on wooden piles. The deck construction is of the usual transverse girder, longitudinal beam-and-slab type with a center driveway and a railroad track on each side of the pier, the easterly track being flush and the westerly one depressed. The pavement consists of wood blocks in the driveway and asphalt on the remainder of the deck. Fenders are of the suspended type. The superstructures will consist of a two-story steel and concrete shed, with a bulkhead building projecting to within 15 ft. of the curb line. The building will contain the offices, waiting rooms, baggage chutes and elevators for the accommodation of passengers for whose service the pier will ultimately be used.

*Chief Engineer, California State Harbor Commission, Ferry Bldg., San Francisco.

FIG. 2. ENTRANCE TO PIERS 30 AND 32, SAN FRANCISCO

A good example of the wooden construction is Pier 41. This is 1081 ft. in length and 200 ft. wide, supported on creosoted piling, with a timber deck and two surface tracks, the center driveway paved with bituminous concrete and the cargo space at the sides with asphalt. The fender line is of creosoted piles protected by Oregon pine sheathing extending to below low water. Unlike most of the piers of similar type no shed will be erected over this structure, which will be used for lumber, structural steel and the like.

All new piers are provided with at least one track, and generally with two, one on the surface and one depressed. Provision is made for the possible future installation of cranes for handling freight by building the substructure and shed columns heavy enough to carry them. Doors are of ample size, usually 22 ft. high and 20 ft. wide, and equipped with steel rolling shutters, which possess the advantage of easy operation, durability and low maintenance cost.

To add to the attractiveness of the waterfront, the old ugly type of shed has been abandoned and an adaptation of the Mission style of architecture (Fig. 2) chosen for the superstructure of piers south of Market St. Those north of the Ferry Depot have been designed on the lines of the Chelsea piers in New York.

BELT RAILROAD

A most important adjunct to the docks is the Belt Railroad, which is operated by the State to handle the commerce of the water front. A decided improvement

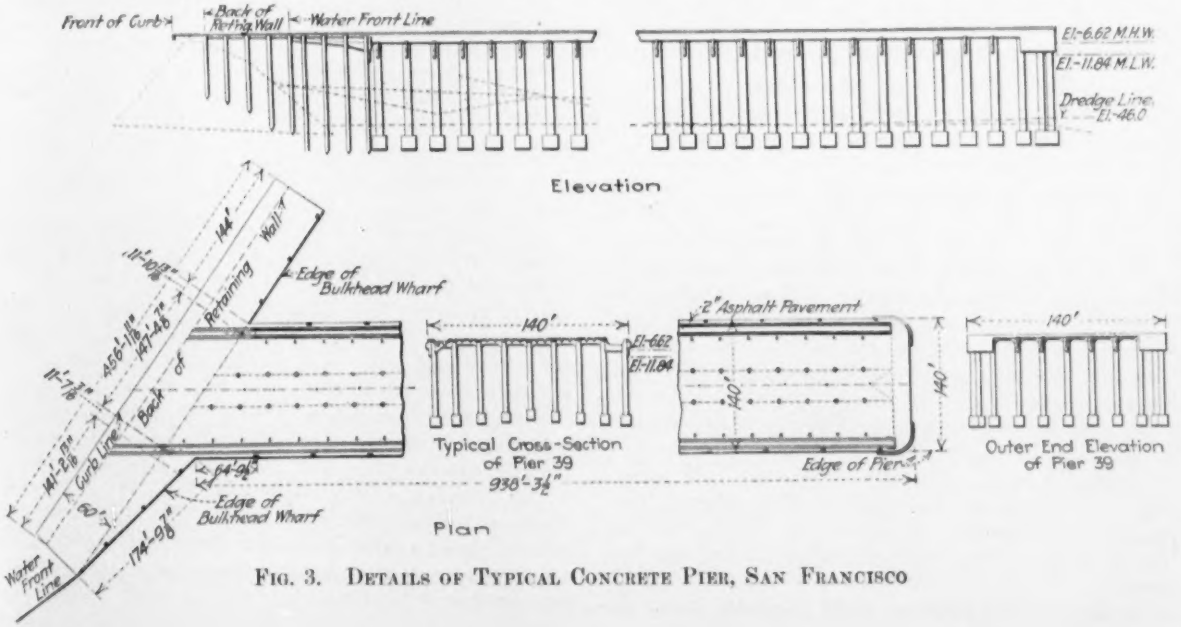


FIG. 3. DETAILS OF TYPICAL CONCRETE PIER, SAN FRANCISCO

in operating conditions was effected by building a 3900 ft. extension across the northern and southern divisions.

Difficulty was experienced in its construction in front of the Ferry Depot, where the foundation is a sand fill over timber platform beneath the mud line. The timber platform is supported by pile bents spaced too far apart to carry trains safely. It was necessary for a distance of 390 ft. to trench the street, drive the required additional piles and lay a new plank platform to retain the sand.

An equally important extension was from the foot of Powell St., its former northerly terminus, to the Government Transport Docks at Fort Mason, and the grounds of the Panama-Pacific Exposition. This necessitated a tunnel 1500 ft. in length under a portion of the Fort Mason Military Reservation. The tunnel is concrete lined throughout, with a clear width of 17 ft. and a clear height above the top of the rail of 22 ft. At the westerly end, concrete retaining walls extend from the portal for 250 ft., their object being to save as much ground as possible for the use of the military post.

The Present Water-Supply of San Francisco

Hydraulic engineers, visiting San Francisco for the first time, will be much interested in the properties and structures of the Spring Valley Water Co., which is at present supplying to the city 42,000,000 gal. daily. A two-day automobile trip can be arranged to include the city distributing system, the more important watersheds and reservoirs, the pumping stations, the filter galleries whence a supply is obtained from the pliocene gravels, and the Calaveras Dam, the largest earth embankment ever designed, which is now in course of construction and was fully described in ENGINEERING NEWS of Oct. 1, 1914.

In the early fifties, when San Francisco was still a village, its water-supply was obtained from shallow wells on the premises of the inhabitants. Later, tanks were filled in Marin County, conveyed by barge across the Bay and the water then distributed by carts in San Francisco. In 1857 the San Francisco Water-Works was incorporated and a year later developed a supply on Lobos Creek, a small stream on the northwest slopes of the Presidio Hills. A small diverting dam was built across the creek and directed the flow into a flume which skirted the shores of the Golden Gate, passed through tunnels under Fort Point and Fort Mason, and discharged into a sump near the north end of Van Ness Ave. Thence it was pumped to the Francisco St. Reservoir, at an elevation of 134 ft., and to the Lombard St. Reservoir, at an elevation of 303 ft., whence it flowed into the distribution mains.

In 1858 the Spring Valley Water-Works obtained a charter from the State Legislature, and in 1860 developed a supply in San Mateo County, on Pilarcitos Creek, whence it brought 2,000,000 gal. daily to San Francisco. The Pilarcitos Reservoir, which has a capacity of 950 million gallons, was formed by the construction of a clay dam 90 ft. high, with a puddle core. The area of the tributary watershed is 5.2 sq.mi. The elevation of high water in the reservoir is 697 ft. above mean tide. At present water is taken from Pilarcitos through a redwood flume conduit, two concrete-lined tunnels and a 30-in. wrought-iron pipe line, to San Andreas Reservoir, which has been formed by the construction of an earth embankment similar in design and dimensions to the Pilarcitos Dam. Besides the water from Pilarcitos, San Andreas Reservoir receives the runoff from a catchment area of 7.6 sq.mi. Its capacity is 6230 million gallons and it is directly connected to the College Hill distributing reservoir, of which the elevation is 255 ft. Through a bypass at Baden, water from San Andreas Reservoir may be diverted to the central pumps, and thence lifted to Lake Honda, at an elevation of 365 ft.

The Crystal Springs Reservoir, which adjoins San Andreas and Pilarcitos, has a watershed of 22.5 sq.mi. Here over 19,000 million gallons are impounded by a concrete dam 145 ft. in height, with a crest length of 600 ft. The dam was so designed that the height can be increased to 190 ft., when 45,000 million gallons will be impounded in years of heavy rainfall.

Lake Merced, with a watershed of 7½ sq.mi., in the southwest corner of San Francisco County, supplies 2,000,000 gal. daily. The quality of the water is inferior to that from the San Mateo watersheds above mentioned. From the combined peninsula reservoirs 21,000,000 gal. are now being supplied. An additional 21,000,000 gal. is brought from Alameda County through two 16-in. and two 22-in. submarine pipes under San Francisco Bay.

The Alameda supply is obtained from Livermore and Sunol valleys, which were formed by faults in the earth's surface, later filled with pliocene gravels by stream flow. The gravels are covered by an impervious clay cap and annually replenished by several Coast Range streams. The water is collected in large filter galleries and wells and pumped into the Sunol Aqueduct, through which it is conveyed to a concrete receiving basin near Niles, at an elevation of 180 ft. Thence it flows by gravity through a 36-in. wrought-iron pipe to the bay shore, under the bay, through the four submarine pipes above described, which connect to a 36-in. pipe on the San Mateo shore. It then passes through the Ravenswood and Belmont pumps to the various distributing reservoirs in the city.

Included in the Alameda system are the undeveloped watersheds tributary to Arroyo Valle and San Antonio Creek, and also the Calaveras Valley which is now being converted into a reservoir with a capacity of 53,000 million gallons, and has a tributary watershed area of 135 sq.mi. The combined catchment areas of San Antonio Creek and Arroyo Valle are over 180 sq.mi. The development of the San Antonio supply has been recommended as a necessary adjunct of the Hetch Hetchy system.

Owing to its exceedingly hilly topography a very elaborate distribution system has been found necessary for San Francisco.

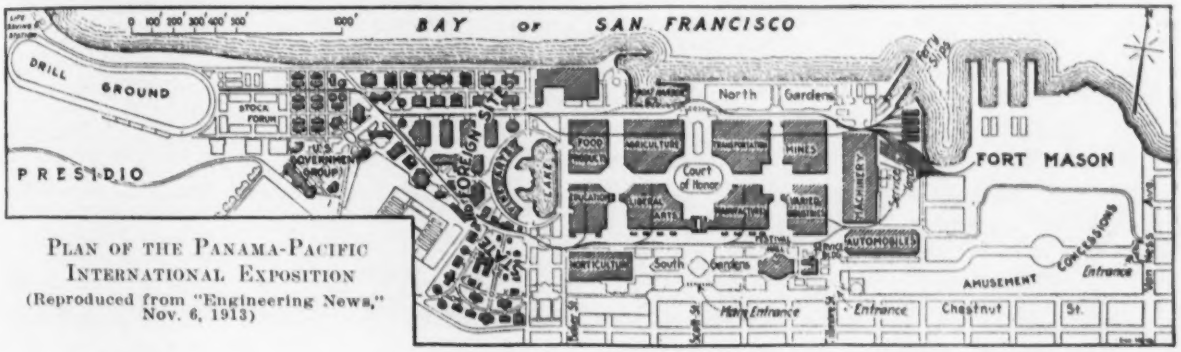
Negotiations are now pending for the purchase by San Francisco of all of the valuable water-producing properties and the distributing system of the company. A careful inventory and valuation of the entire system was recently made by the city engineer, assisted by a corps of consulting engineers. On the basis of his findings an advisory water committee, consisting of the mayor, the city attorney, two members of the board of supervisors and a former chief justice of the supreme court, recommended the purchase at a price of $34,500,000. Experts employed by the company, among whom were Allen Hazen of New York and Leonard Metcalf of Boston, and other noted engineers, placed a value of over $42,000,000 on the property the city proposes to purchase. The bond election will be held on Apr. 27, 1915.

Engineering Problems of the Panama-Pacific Exposition

By A. H. Markwart*

SYNOPSIS—The great international exposition which is to be opened this week at San Francisco is the work of engineers. The story of its creation is here briefly told by one of the engineers who has borne chief responsibility for this vast work. There is no doubt that the most wonderful of all the exhibits at San Francisco is the Exposition itself. In a few short months the constructive genius of engineers has transformed an area of tide-swept marsh to a beautiful park in which rise a series of vast palaces richly adorned. Every branch of engineering has contributed to the final result; and that the entire exposition has been finished in time and within the original estimate of total cost is not the least of the items for which engineers may well take credit.

Announcement of the successful completion of the construction work of the Panama-Pacific International Exposition prior to the opening day (Feb. 20, 1915) and at a cost within the sum set aside for the purpose, is certainly of interest to engineers. Although the problem was to a large extent an architectural one, engineering talent nevertheless was primarily responsible for the work from inception to completion.



Plan of the Panama-Pacific International Exposition
(Reproduced from "Engineering News," Nov. 6, 1913)

Exposition engineering may be said to be a combination of general construction, city engineering, city planning and city management. The many difficult cost problems arising out of the commendable zeal of the architects, sculptors and artists to produce superlatives were happily solved by the engineers in that they controlled the budget with a firm hand; that this control was not unintelligently exerted will be seen in the general artistic results, but the cost did not exceed the allowance.

Expositions are short lived. Exposition buildings, therefore, must be temporary but yet safe and convenient no matter how crowded. First cost and salvage must be considered. A definite program is almost an impossibility, consequently flexible designs are essential on account of the many changes which are constantly demanded. The ideal exposition engineering should attain low cost, speedy completion, sufficient strength and capacity, a short life, low wrecking cost and high salvage value.

Opportunities for such a wide range of work as was here necessary are seldom presented to the engineer. A good organization and plenty of assistance were necessary to cover the varied fields. At one time as many as 23 estimators, 66 architectural draftsmen, 140 civil engineers and draftsmen, 23 inspectors, 34 electrical engineers and draftsmen and 50 clerks and stenographers were on the division of works' payroll.

History, Progress and Scope

The Exposition was first suggested in one of the commercial organizations of San Francisco in January, 1904. In January, 1906, an Exposition bill was introduced in Congress; but in April, 1906, the great earthquake and fire occurred.

In October, 1909, San Francisco had the Portola Festival which caused a revival of interest in the proposed Exposition. The Panama-Pacific International Exposition was incorporated Mar. 22, 1910, and at a big mass meeting on the floor of the Merchants' Exchange there was subscribed in about two hours the significant sum of $4,089,000. At a special session of the Legislature Sept. 26, 1910, two constitutional amendments were proposed for the approval of the voters—one to raise $5,000,000 by a state tax and the other to permit San Francisco to bond itself for the same amount. Both were voted and passed on Nov. 8, and on Nov. 15, the city passed a charter amendment covering the $5,000,000 bond issue. A joint resolution recognizing the Exposition passed Congress and was signed by President Taft.

The hydraulic fill in Harbor View basin was begun Apr. 13, 1912, and finished Sept. 7, 1912. The contract for Machinery Palace was let Jan. 7, 1913, and the work was completed Mar. 10, 1914. The last large contract, that for the California Building, was let May 25, 1914, and finished Jan. 25, 1915. All Exposition construction except minor small pieces will be completed by the opening day, Feb. 20, 1915. There were 750 construction contracts let, covering sums ranging from $500 to $800,000.

*Assistant Director of Works, Panama-Pacific Exposition, San Francisco, Calif.

Thirty states and territories and twenty foreign governments have erected pavilions. Some 60 concessions have erected quarters in the Zone or Amusement Street. Approximately 1500 exhibitors will erect booths within the exhibit palaces.

Arrangement of Buildings

By reference to the block plan (reproduced herewith from Engineering News, Nov. 6, 1913), it will be seen that the main Exhibit Palaces are twelve in number. They furnish an exhibit area of 64.5 acres. Eight of these form the Main Group and although separated by open courts and avenues, they are connected here and there with various towers, arches and other architectural monuments, so that these eight buildings will in reality form one immense building with open-air interior courts.

The five other buildings form separate units. Fronting the main entrance to the grounds and on the north and south axis is the Tower of Jewels, the gateway to the Court of the Universe.

Aeroplane View
Main Group of Exhibit Palaces
Panama Pacific International Exposition
San Francisco, Dec. 13th, 1914
Copyrighted by GABRIEL MOULIN, 1914

Aëroplane View of Exposition Buildings

Materials and Methods of Construction

To secure economy, the Exposition structures being temporary and San Francisco being near large lumber producing centers, wood was chiefly used for the buildings.

With the exception of the Palace of Fine Arts, the dome and dome substructures of the Palace of Horticulture and the Tower of Jewels, the frames of all the buildings, including the wall studding and the sheathing, are of timber, requiring seventy million board feet.

Fire walls were used, composed of 6-in. concrete reinforced by ½-in.sq. steel bars 18 in. c. to c. in both directions, and are supported by concrete spandrel beams, which are in turn supported by reinforced columns. These columns rest upon concrete caps supported on wooden piles. About 6400 cu.yd. of concrete were required for this purpose. These fire walls are used in place of the regular construction of timber columns, studs, grooved wood sheathing, lath and plaster.

The Palace of Fine Arts was constructed with a steel frame with walls and roof of cement plaster on metal fabric. The roof slab is approximately 3 in. thick, while the vertical walls have a thickness of 2½ in. Ribbed metal lath, No. 24 gage, with a total thickness of the fabric of ¾ in. was used. The lath sheet is laid horizontally and fastened to the steel frame by means of special wire clips placed 5 in. on centers. The corrugations of the lath interlock at the ends and are wired with No. 16-gage tie wires at intervals of 12 in.

The cement plaster consisted of one part portland cement, three parts sand and a small amount of hair, well tempered with lime mortar to set up hard and firm. The first coat of plaster was applied to the fabric on the outside and floated to an even surface with a depth of at least ⅜ in. over the extreme projections of the metal. After the first coat had set, the opposite side of the metal was plastered as noted for the first coat, allowing for a total thickness 2½ in., including the final plaster coat. This gave essentially a reinforced wall of a minimum thickness. Concrete was not used because it would have been necessary to provide a thicker wall with a consequent higher cost. There is a final coat on all plastered walls of hard wall plaster, colored and stippled in imiitation of travertine. This surface is the characteristic finish on all of the exhibit palaces.

Similar wall construction to that just described was used for the Tower of Jewels, except that the plaster wall was supported by a wooden instead of steel frame. In the design of this tower, the type of construction adopted was a steel structure which supports the timber framework of the floors and walls. While this construction is not fireproof, it may be termed fire-resisting, approaching what is commonly known as "mill construction."

In general all footing grillages, whether for pile or spread footings on earth, are of timber. However, there

were places where footings have been made of concrete reinforced with steel bars.

Transformer vaults for alternating-current transformers are located in all the main exhibit palaces. Since these vaults were required to be of fireproof materials they have been built of reinforced concrete throughout. Such vaults are approximately 11x20 ft. and 9 ft. high with 6-in. walls reinforced with ⅜-in. square bars 18 in. on centers horizontally and vertically.

In concluding the summary of construction methods and materials, it should be said that every effort was made to avoid the use of permanent materials wherever this was possible. The fire-resistant qualities of concrete, with its strength and cheapness when compared with steel and brick construction, showed it to be a logical material where fire-resisting materials were required. Steel frames were used only when the type, character and size of the construction were such as would not permit the use of timber.

Hydraulic Fill

Two hydraulic fills—1,300,000 cu.yd. at Harbor View and 400,000 cu.yd. at the Presidio—covering an area of 184 acres, were made at a cost of $302,000. The larger fill which cost $218,000—producing 70 acres of Exposition area—is worthy of particular mention.

Harbor View material was pumped by means of a standard dredge from a depth of 30 to 50 ft. through pipes varying from 600 to 2000 ft. in length. The discharged material had 8 to 10% solid matter and that left in the fill was approximately 70% sand and 30% sea mud.

The fill in the Presidio was very shallow and did not exceed 6 ft. in depth. The material was mostly sand with a slight percentage of mud and frequently large boulders and was pumped from 800 to 1500 ft., the dredge standing at all times not less than 300 ft. from the shore line.

The fills proved satisfactory, as the installation of roads and gardens and the work of pile driving and construction of the Exhibit Palaces took place immediately upon completion of the fill, a procedure which is unusual in the case of many new fills. There has been no damage from settlement.

Gardens

Since almost all of the site was of sand, 55,000 cu.yd. of loam and 30,000 cu.yd. of fertilizer had to be handled in order to create the many gardens and parking spaces. In general, the site was barren of foliage. The 68 acres of finished gardens at a cost of $497,000 present lawns, small trees, large trees, shrubs, bulbs, annuals and perennials to an extent that seems unbelievable when the original condition of the site is remembered.

Sewers

The sewer system consists of 54,500 ft. of combined sewer, 20,000 ft. of sanitary sewer and 55,500 ft. of storm sewer embracing 106,000 lin.ft. of 4- to 24-in. vitrified pipe and 22,000 ft. of 10- to 51-in. wooden-stave pipe and 2000 ft. of 2x2-ft. to 2x4-ft. box culvert. This system cares for the drainage of about 435 acres and discharges the storm waters from roofs and grounds and the sanitary drainage from the States, Foreign Exhibits and Concession Districts, into the Bay; it was built at a cost of $141,000, not including catch basins nor catch-basin connections, or approximately $290 per acre drained. The sewer system was described in Engineering News, Nov. 27, 1913. For comparison, the Jamestown Exposition had 12,000 lin.ft. of sewer ranging in size from 6 in. to 10 in.

Roads

One of the most annoying problems which arises in exposition work is that of roads during the pre-exposition period. The traffic is so heavy that the roads are generally reduced to mud or dust by the opening day. Road making and the work of other construction must be carried along simultaneously with consequent resulting conflict. Many of these difficulties were avoided at San Francisco by the use of temporary plank roads laid throughout the grounds, mainly in the garden plots. Red-rock macadam base was laid prior to the greatest bulk of building construction, but after sewer, water and other pipes and conduits were in place. The red rock, having a high percentage of clay, was easily compacted by watering and rolling, after which traffic was permitted on the roads. Finally, at intervals during the progress of the general work, various roads and portions of roads were barred to traffic and then brought to a grade and surfaced in general with a ⅜-in. asphalt and sand mastic or sheet asphalt of a thickness of ¾ in. or 1 in. or 1½ in., depending upon the ultimate use to which any given road was to be put. To protect this asphalt, the road plank was again laid, this time over the asphalt, over which the balance of construction materials were hauled shortly prior to the opening day, when the road plank was finally discarded. Many annoyances and obstructions were thus obviated.

Not including irregular areas, there are 15 miles of roads and paths varying in width from 64 to 10 ft. The total area of paved roadways and paths outside of that charged to courts and buildings is 3,278,000 sq.ft., built at a total cost of $445,000, not including the cost of temporary road planks, but including wooden curbs and catch basins and branch sewer connections.

Approximately 1,247,000 sq.ft. of the same type of pavement was laid in connection with the buildings and courts. The red-rock macadam base averaging 8 in. thick cost about 8c. per sq.ft., including the quarrying by means of a steam shovel at the quarry site directly across the bay and the barge transportation therefrom to the Exposition. Asphalt mastic, ⅜ in. thick, and sheet asphalt, ¾ in., 1 in. and 1½ in. thick, were laid at a cost of 1¹/₉, 1.9, 2.9 and 3.77c. per sq.ft. respectively.

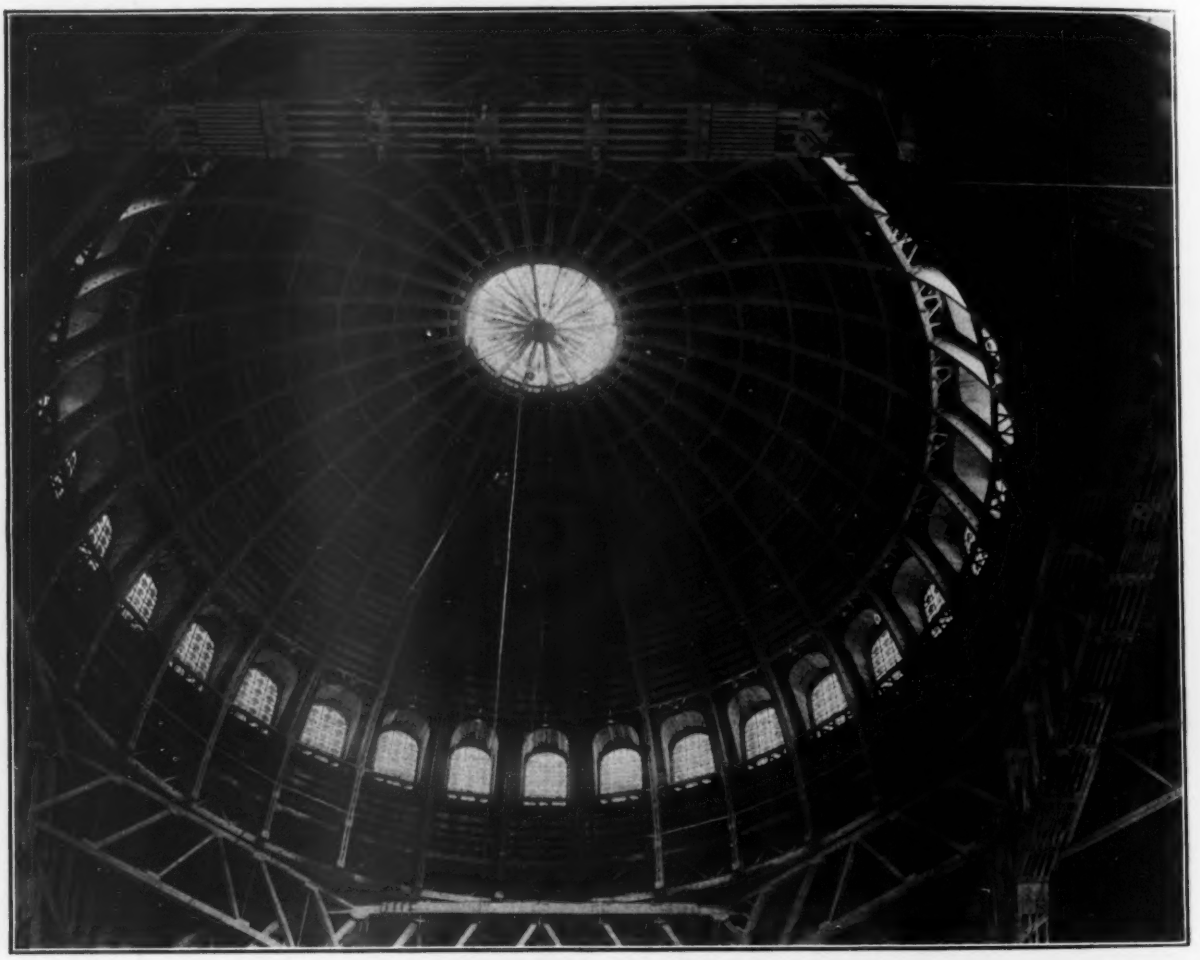
Palace of Machinery

Of the wooden frames, that of the Machinery Building is perhaps the most interesting, this being, it is believed, the largest timber-framed building in point of cubic contents ever constructed. The building is 968 ft. long and 368 ft. wide. It has three longitudinal bays 75 ft. wide and 121 ft. high with longitudinal side aisles 70 ft. wide and 53 ft. high. There are three transverse bays 75 ft. wide and 136 ft. high. Arched trusses, analyzed as simple trusses, span the main longitudinal and transverse bays and have their spring line at 66 ft. and 81 ft. from the floor respectively, which is unique, since it leaves these unsupported heights of wooden columns. The building, (as described in Engineering News of Nov. 6, 1913) covers 370,000 sq.ft., has a space of 38,000,000 cu.ft., contains close to 8,000,000 ft. b.m. of lumber and cost $630,000 complete.

Main Group

The Main Group of eight palaces is 2756 ft. long, 1250 ft. wide and 43 acres in extent, all with wooden structural frames. Each building has major longitudinal and transverse aisles with a dome at the intersection. The main aisle trusses in clerestories are three-hinged arches 82 ft. span and 96 ft. high, with a spring line 51 ft. above the floor. The domes, 100 ft. in diameter and 162 ft. high, consist of 32 ribs (each pair having been analyzed as a three-hinged arch), resting upon a circular girder which in turn is supported by four girders forming a square of 102 ft., at the corners of which are framed diagonal girders affording four additional supports for the circular girder. An unsupported height in one direction of 90 ft. for dome column prevails. The roof over all portions of this group not covered by the domes and clerestories is supported by modified Howe trusses 70- to 80-ft. span, 26- to 27-ft. centers of an average depth of 10 ft., having their lower chords 40 ft. above the floor.

The Court of the Universe, the main court of the Exposition, has two Triumphal Arches at its east and west entrances. These arches are immense timber structures, each of which may be structurally described as a huge, rectangular box 60 ft. wide by 127 ft. long and 147 ft. high. Through this box is passed a barrel vault with a width of 52 ft. and a height of 90 ft. The walls of the structure consist of the usual travertine plaster (Engineering News, Nov. 6, 1913), grooved sheathing laid and studs supporting by a timber frame of post and truss construction. The exterior is richly treated with staff ornament, color and mural paintings, and the arch is surmounted by a sculptured group, weighing approximately 43 tons.



A Typical Dome on One of the Main Group of Buildings

Tower of Jewels

From an engineering and architectural standpoint, the Tower of Jewels is unique. The structure is 435 ft. high; with the exception of the new Smith Building in Seattle, it is safe to state it exceeds in height any structure west of Chicago.

An uninterrupted clear height was necessary to produce the barrel vault. This was accomplished by the use of two-hinged arches approximately 126 ft. in height from the bottom hinge to the center of the lower chord, having a span of approximately 115 ft. on pin centers. On top of six of these two-hinged arches rests the balance of the huge structure.

Of particular interest are the special cast-steel spherical bases for the support of these main frames. It was be-

fied that the use of this type of base would facilitate erection and assure vertical reactions in case of settlement of the foundation or changed conditions.

The novel and spectacular feature of this structure is the many imitation jewels hung upon its surface. The various parts of this Tower have been picked out by means of these jewels which are from 21 to 47 mm. in diameter. They have a cut similar to the Sumatra cut, the exact number of facets, however, having been computed and checked by experiment. These imitation gems are of Austrian manufacture, of the highest grade, with tin-polished facets. About 100,000 of them are used on the tower and they are mounted in such a manner as to have easy play in the air currents and glisten and sparkle in the light. Searchlights with colored screens throw beams of light upon the Tower and other structures which contain these jewels during the evening illumination.

The Tower proper contains 3,440,300 cu.ft., has 1403 tons of structural steel or 0.816 lb. per cu.ft. and cost in place 4c. per cu.ft. The entire architectural feature including two side colonnades contains 3,907,500 cu.ft. and cost 10.67c. per cu.ft. of inclosed contents.

Palace of Fine Arts

The Palace of Fine Arts, built of steel and fire-resistant materials, is curved in plan, being about 950 ft. long measured along the center arc, and about 135 ft. wide, covering 126,000 sq.ft.

Three-hinged arches 131-ft. span and 36-ft. centers—somewhat unusual on the Pacific Coast—provide the interesting structural feature. The height from floor to center hinge is 48 ft. Underneath the wooden floor, 8-in. steel channel ties connecting the lower hinges resist the arch thrust.

These three-hinged arches, weighing approximately 25 tons each, were erected in halves, each half being first set upon its steel base, after which the ends were swung together at the center and the center pin slippd into place, the arches meanwhile being supported by the derricks until the cross bracing was set. The steel frame cost $123,000 and weighed 1437 tons, or 0.492 lb. per cu.ft. of inclosed contents. The total cost of the building with its rotunda and colonnade was $630,000, or approximately $3.10 per sq.ft. area covered.

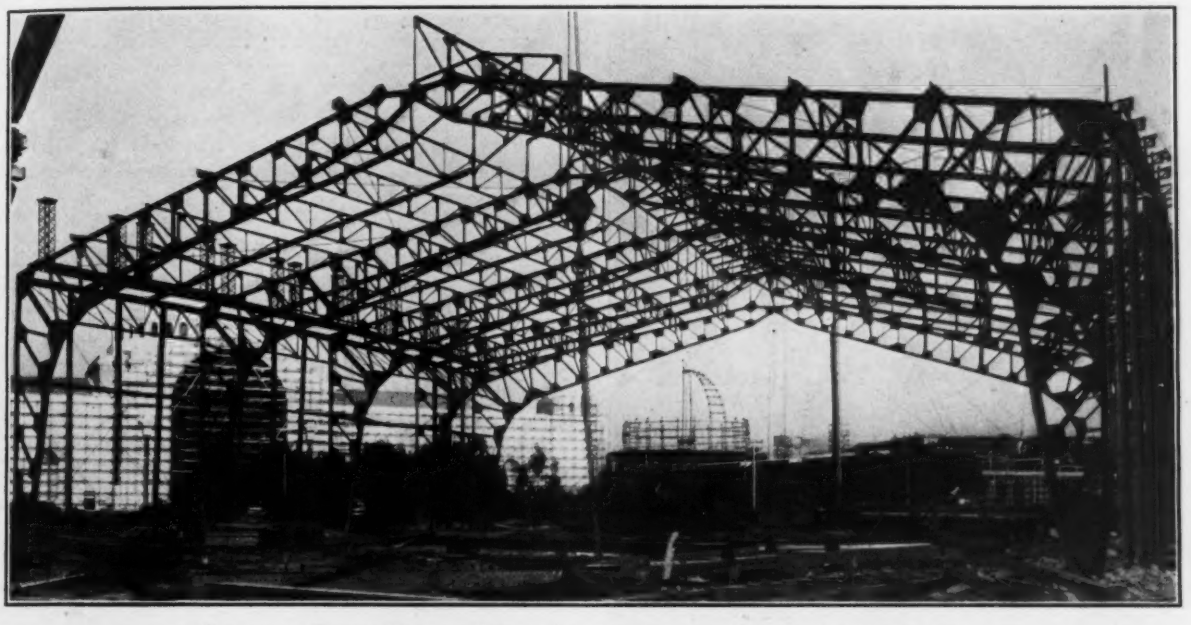
Palace of Horticulture

Interest attaches to the all-glass dome of the Palace of Horticulture. Its supporting frame was figured as a true dome; it consists of 24 steel ribs connected by 11 horizontal rings. The upper portion of the dome is hemispherical with a diameter of 152 ft., while the lower portion is a cylindrical shaft with the same diameter and a height of 24 ft., the whole being supported upon plate girders and trusses, framed between eight structural piers 65 ft. in height.

An idea of the magnitude of this dome may be had when it is compared with some of the most famous domes now in existence. The diameter of the Pantheon of Rome was 142 ft.; that of the Duoma of Sta. Marie del Fiore at Florence 139 ft.; the United States Capitol at Washington, D. C., 135½ ft.; while the famous dome of St. Peter's at Rome is 139 ft. in diameter. The dome of the Palace of Horticulture at the World's Columbian Exposition at Chicago had an outside diameter of 187 ft.; the dome under discussion, however, exceeds that of the Chicago dome in one dimension, namely, its extreme height being 185 ft., while that of the Chicago dome was 135 ft.

To secure all the stiffness possible in the dome frame proper, all connections were riveted. However, all connections below the dome were bolted in order that the dismantling of the structure would be facilitated.

The steel frame rests upon a timber grillage supported by piles. The weight of the steel in the superstructure of the dome proper, which consists of all the structure above the level of the top of the plate girders, is 200 tons. The surface area of this portion is 47,000 sq.ft. so



Erecting Three-Hinged Steel Arches for the Palace of Fine Arts

that the weight of the steel in the dome proper per square foot of superficial area is 8½ lb. The volume of this portion is 1,317,000 cu.ft., making the weight of steel per cubic foot 0.304 lb. The weight of steel in the substructure or that portion of the steel frame below the level of the top of the plate girders is 300 tons, making total weight of steel in the frame 500 tons. The cubical contents of the volume inclosed by the steel frame is 2,817,000 cu.ft., giving an average weight of steel per cubic foot of 0.358 lb. The cost of the steel erected was approximately $55,000.

Festival Hall

This building—a huge dome with large arched openings on two sides—in effect a hemisphere of 86 ft. radius, in-

The Tower of Jewels by Night Illumination

tersected on one axis by a cylinder of 98 ft. diameter, necessitated unusual framing. The supporting structure may be described as a pyramidal dome of 140 ft. diameter framed of 16 trussed ribs, and supported on four main piers and eight columns. The dome is surmounted by a lantern 65 ft. high. The four ribs occurring over the arched openings are carried by two trusses spanning a distance of 77 ft. between the four piers referred to.

The pyramidal dome is designed as a true dome, the upper chords of the trussed ribs taking the whole weight of the roof and ceiling in compression, the ring stresses being all compression and taken by timber struts, specially framed and wedged into the ribs. The ring tension at the supports is received by two 3⅛-in. rods, fitted to special castings on the ends of the ribs. The lower chords of the trussed ribs and also the diagonal web members take stress only from wind.

The dome roof, with a diameter of 172 ft., is built up of roofing and sheathing supported on 2x6-in. rafters resting on light studded walls. These walls are carried by special beams spanning from rib to rib, and directly above but independent from the dome ribs. This consideration is an important one in a dome of this type.

The interior domed ceiling, with a diameter of 136 ft. 8 in., is suspended from the trussed ribs. Particular attention was paid in erection to provide that the trussed ribs would not act as trusses until the total dead load was on the roof. This was accomplished by special connections for the diagonal web members.

In erecting the dome, a central tower was constructed from the floor to the under side of the circular truss. Wedges and jacks were placed between the top of the tower and the bottom of the circular truss, to insure an even distribution of load on the dome when the tower was removed.

The building cost $253,000, not including a $43,000 organ, nor any of the furnishings, and will seat about 2700 persons.

Water Supply

Original plans contemplated that the Spring Valley Water Co. would deliver to the Exposition from 2 million to 3½ million gallons of fresh water per day, these quantities having been preliminarily determined as those required on days of small and days of large attendance respectively.

The company, however, found it could not undertake to bring into the city an additional supply of water to serve the Exposition as well as the needs of the city during the Exposition period. The average daily city consumption for 1913 was approximately 40 million gallons and it was estimated that this would reach 55 million gallons by the early part of 1916.

One million gallons has been secured from Lobos Creek and one to one and one-half million gallons from wells in Golden Gate Park, the balance will be furnished from wells on the Exposition grounds and from the Spring Valley Water Co. The water supply will be filtered.

The water is stored in the Presidio reservoir at an elevation of 375 ft. To reduce the pressure to 80 lb. in the distribution system, a pressure break consisting of standpipe, tank and automatic altitude control valve, has been installed below the reservoir.

The distribution system within the grounds and the supply system and equipment without the grounds, each cost $100,000.

Electric Energy

The Exposition has entered into a contract with the Pacific Gas & Electric Co., which supplies practically all the central part of California with electric energy and gas, having over 90,000 kw. in hydro-electric installations and approximately 100,000 kw. in steam installations. The

contract stipulates that for the Exposition period, the Exposition shall be supplied with three-phase, 60-cycle alternating current at approximately 11,000 volts or 4000 volts, as may be determined. The electric company is obligated by its contract to furnish at any time not more than 9000 kw. in the aggregate between the hours of 5 and 7:30 in the afternoon of any day, not more than 15,000 kw. in the aggregate at any other time unless the company is able to spare an additional amount from its other consumers.

The energy is to be delivered at a substation built in the west end of the Sierra & San Francisco Power Co.'s power station, about 525 ft. east of the Palace of Machinery.

The 18,000-kw. steam plant of the Sierra & San Francisco Power Co. is to be kept in constant operation, so that in case of interruption of Pacific Gas & Electric service to the Exposition, the load may be taken over without delay by the Sierra & San Francisco Power Co.'s plant. The energy used by the Exposition company is transmitted from a 50,000-kw. steam station in the southern part of San Francisco. The current is led underground across the city through three 11,000-volt No. 0000 cables to the Exposition grounds.

The electric company receives for capacity reserved during the Exposition period $18,000 per month, plus an energy charge of $\frac{6}{10}$c. per kw.-hr. for energy actually consumed. The Exposition has a similar method of charging its customers.

Telephone System

A complete telephone system has been installed to handle special Exposition service. Wires and cables are underground, duct space having been provided with the electric conduits. Provisions have been made to handle 1000 subscribers as well as the inter-exposition business of the Exposition company. The central equipment and organization are those of an ordinary city of 10,000 people.

Passenger Transportation

Passenger transportation within the grounds will be accomplished by the use of automobiles, storage-battery chairs, and a miniature steam railway. The miniature railway will run from a point to the east of the south end of Machinery Building, thence along the Marina to the westerly end of the grounds. No other means of transportation will be provided.

Traffic outside the Exposition grounds will be handled by the United Railroads and the Municipal street railway.

Garbage Disposal

A contract has been let for the disposition of all Exposition refuse by means of a single-unit garbage-reduction process, including the collection by means of motor trucks especially fitted up to receive the filled cans. The garbage is treated in air-tight steel tanks, the grease removed and garbage meal for stock and fertilizer made from the tankage. Arrangements are made for participants to use separate cans for organic matter and ordinary waste—the waste as far as practicable becoming the fuel supply for the operation of the reduction plant.

Fire Protection

As the frames of nearly all the buildings are of wood, it will be seen that there is a tremendous fire risk. The fires at the Chicago Exposition and the burning of the buildings at Brussels indicated that fire protection and fire prevention must be made a part of the construction program.

Illumination of North Wall of Mines and Transportation Building

The measures adopted include a regular equipment of fire-fighting apparatus, such as motor-driven fire engines, hose wagons, hook and ladder trucks, etc., a high-pressure water system throughout the grounds and buildings with a static pressure of 300 lb. per sq.in. (see Engineering News, Nov. 27, 1913), a low-pressure secondary water system throughout the grounds and buildings with a static pressure of 80 lb. per sq.in., automatic sprinklers throughout the interior of most buildings and open cornice sprinklers on buildings facing each other and spaced 150 ft. or less, a regular fire-alarm system and automatic alarm circuits, and, finally, such protective devices as wheel and hand chemical extinguishers.

An innovation in exposition-building construction is the use of concrete fire walls, which extend from the ground to the top of the various parapets and subdivide the Main Group of buildings into separate units for the purpose of preventing the spread of any fire which might arise in any given building of the group. These walls are located at the ends of structures connecting two buildings across an intervening court.

Costs

The costs given herein were made up by the recapitulation of actual force account expenditures and contract obligations to Dec. 1, 1914, to which was added an estimate of the financial obligations between this date and Feb. 20, 1915.

The total cost of the general construction work, including clearing the grounds, grading, sewers, water supply,

roads, pavements, wharves, railways, warehouses, temporary buildings, race track, drill grounds, polo field, athletic field, etc., was $2,080,000.

Not including work within buildings, the mechanical and electrical features of the Exposition, covering the overhead and underground distribution system, street decorative lighting, refuse-disposal plant and telephone system, cost $430,000. Fire protection cost $179,000, not including fire walls, motor-driven fire apparatus, or high- and low-pressure water systems.

The gardens and planting represent an investment of $497,000.

Expenditures for the buildings, with related decorative painting and temporary plank roads for handling lumber and other material, aggregated $5,429,000. The included the fire walls, foundation piling, plumbing and electrical work, exterior decorative painting, but not the automatic sprinkler system nor the cost of the plans and specifications.

Purely decorative features were, for construction and accounting purposes, segregated. These consist of the following: Courts of the Universe, Four Seasons, Abundance and Palms and Flowers, with the related decorative painting; Art Gallery Pool; South Garden architectural treatment; fountains; seawall treatment; Fulton Basin treatment; entrances and exists; flags and banners; sculpture; mural paintings; Exposition jewels; and music concourse. The expenditure in this direction was $1,889,000.

"Miscellaneous" items, such as drinking fountains, benches, furniture, scintillator for night lighting displays, boat landings, etc., cost $107,000.

Including salaries of administrative officers, architects' fees, salaries of all draftsmen and architects employed by the Division of Works, salaries of engineers and draftsmen of the civil-, structural-, mechanical- and electrical-engineering departments, plans and specifications, stationery, blueprinting, office expense, etc., the operating cost of the Division of Works was $1,060,000.

The cost of the site in one way or another up to the opening day was $1,162,000. This covers leases, rentals, purchases, assessments and all incidental expenses in connection therewith.

In addition to the activities undertaken by the Exposition upon the Exposition Grounds, there has also been erected by the Exposition an Exposition Auditorium at the San Francisco Civic Center, on a site allotted by the municipality for the purpose. This is a permanent fireproof building with a capacity of approximately 10,000 people and it conforms to the requirements of the City of San Francisco for its Civic Center. The total cost of this building in round numbers was close to $1,290,000, of which the City of San Francisco paid $210,000, leaving a net cost to the Exposition of $1,080,000. This sum was carried in the budget and covers the building complete with a $40,000 organ, the fixed and movable opera chairs and the cost of the plans and specifications.

While not wholly an Exposition activity, the California Building was built by it, chiefly out of funds raised by an association of California counties. The total cost of this building was approximately $416,000 to which the Exposition subscribed the sum of $150,000. The full cost was carried in Division of Works' budget and covers the building proper, all appurtenances, the preparation of adjacent grounds, the gardens and furniture.

In connection with cost figures, it is well to note that practically all the electrical apparatus was loaned by the Pacific Gas & Electric Co. in consideration of an exclusive contract for energy; under this arrangement the company laid and paid for all gas mains. A further reduction of cost lay in the acquisition of much apparatus on exhibit and rental bases or at special reduced prices.

Definite lines of demarcation between the pre-Exposition and Exposition periods were not possible, as far as some of these pre-Exposition accounts were concerned, consequently some of the obligations may actually be slightly more or less than the sum named. This variation will probably be not greater than 1 per cent. either way. Some of the obligations above outlined were not created until after the opening day. However, most readers will be able to form significant conclusions relative to probable gross construction cost.

This information may be briefly summarized as follows:

General construction	$2,080,000
Mechanical and electrical features	430,000
Fire protection	179,000
Gardens and planting	497,000
Buildings	5,429,000
Decorative features	1,889,000
Miscellaneous items	107,000
Operating equipments	96,000
Divisions of Works, Administrative, Engineering and Architectural and Superintendence	1,060,000
Site acquisition	1,162,000
Exposition Auditorium	1,080,000
California Building	416,000
Total of all Division of Works' activities and budget as authorized Dec. 8, 1914	$14,425,000

About $17,160,000 represents the total expenditures of all divisions and departments of the present Exposition to the completion of the pre-Exposition work, divided up approximately as follows:

Division of Works' activities (from the above)	$14,425,000
Division of Exhibits	400,000
Division of Concessions and Admissions	110,000
Division of Exploitation and Publicity	450,000
Special unattached departments	450,000
Administration	375,000
Miscellaneous expense	375,000
Promotion	375,000
Total	$17,160,000

Expenditures are given in round numbers and are taken from the best information now available. Some changes will occur when the books are closed but will not probably be material.

From the above will be taken a unit Exposition cost covering all pre-Exposition activities of $266,000 per acre of official exhibit area. It appears that construction cost alone at Chicago was $182,000 per acre, that of Buffalo $292,000, while that of St. Louis was $150,000 per acre.

The operating expenses will be covered by the gate receipts and percentages from concessionaires; present indications are that the attendance is going to be good. There has been a total paid attendance of 756,331 persons during the pre-Exposition period from September, 1913, to Jan. 10, 1915, from which the receipts were $189,000. In order to finish the work without interruption, the grounds after Jan. 10 and until the opening day were closed to the public. The pre-Exposition income paid the cost of gatemen, guards, upkeep of finished pieces of work, maintenance of roads, gardens and other incidental items prior to the opening day.

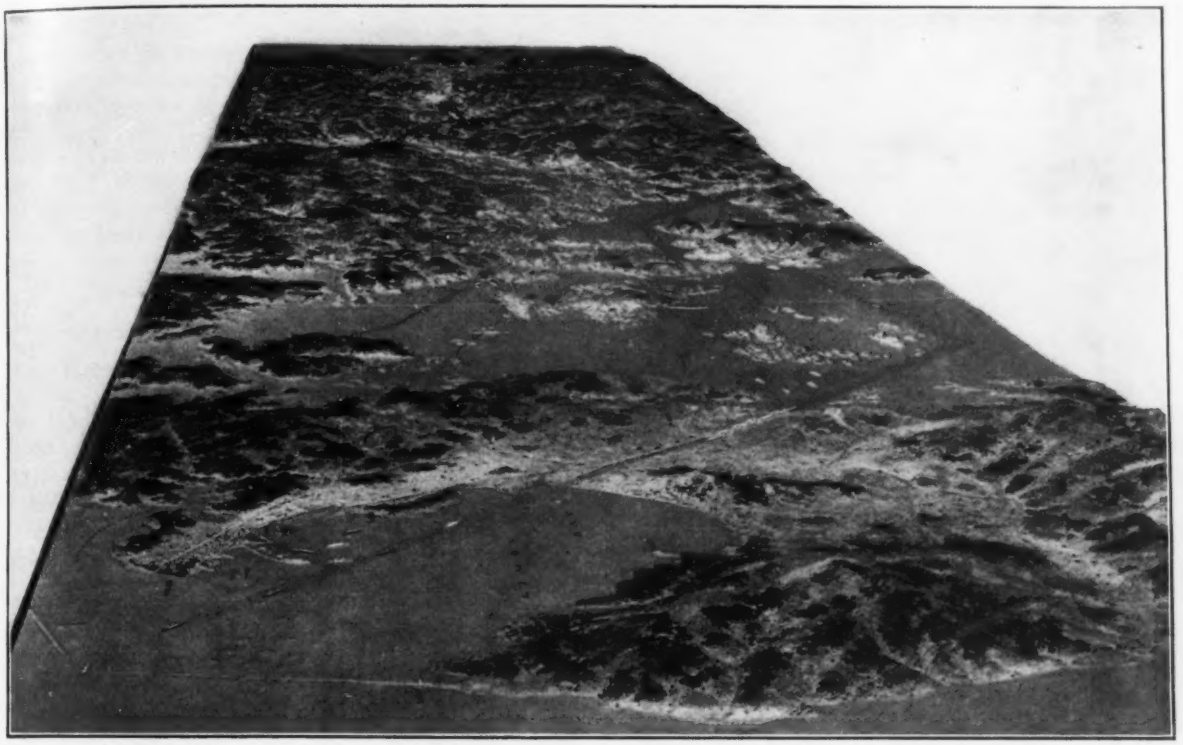
Preliminary estimates of operating costs indicate an Exposition period expense of $12,000 a day which will be met by the gate receipts. Ten million paid admissions are predicted during the 288 days the Exposition is open. This figure is advanced by experienced Exposition authorities and it is believed to be reasonable considering the attendance during the pre-Exposition period.

A Great Relief Map of the Panama Canal

There has just been completed at Washington one of the largest relief maps ever constructed. It is a map of the Panama Canal extending from ocean to ocean. The map is plotted on a scale of 1:5000 for the horizontal, slightly larger than 1 ft. to the mile, and 1:2500 for the vertical. As the map covers the 10-mile width of the Canal Zone, the entire map is 10 ft. 6 in. in width and 50 ft. in length. The length of the map is in fact so great that the accompanying photograph taken from the Atlantic end of the map shows only that end clearly, and the Pacific terminal of the canal almost disappears in the diminishing perspective. We have, therefore, supplemented this view with a second view showing the Pacific part of the map, extending as far northward as the deepest part of the Culebra Cut.

To give a realistic effect to the map, it has been colored to correspond with the natural features, such as water, forest-covered area, etc., and tiny models of vessels are placed along the map in the sailing channel.

In making this relief map the official topographic maps of the Canal Zone were used as a basis. These maps were mounted on pasteboard about 1/8 in. thick and carefully cut out along each 20-ft. contour. These cardboard outlines were then pasted upon each other in the proper position; and to smooth up the intervals between the contours and make uniform slopes, modeler's clay was used. In this manner a correct map was built up over the entire area, the work being done in ten sections, each covering the 10-ft. width of the map and 5 ft. in length. When one of these sections was completed, a mold was taken from the original, and the final relief map was cast in this mold in papier mache. When the section thus cast was thoroughly dried, the surface was smoothed, and it was



A Large Relief Map of the Panama Canal
(Modeled for the Panama Canal by Howell's Microcosm, Washington, D. C.)

View of the Pacific End of the Panama Relief Map

then painted and lettered and fitted with the models of war vessels, ships, buildings, locks, etc.

This relief map of the Panama Canal has been constructed by Howell's Microcosm, of Washington, D. C., of which Mr. Geo. Robertson is manager. This concern has constructed many relief maps for the government during past years. The relief map is to be exhibited in the Liberal Arts Building of the Panama-Pacific Exposition, and after its close will be returned to Washington and set up in the National Museum.

There has also been constructed a working model of the Pedro Miguel lock in the canal. The model is made on a scale of 1 to 600 and measures 10 ft. in length and 3 ft. 6 in. in width.

The Working Model of the Panama Canal at the Exposition

A working model of the Panama Canal will be one of the most interesting exhibits to engineers in the amusement zone of the Panama-Pacific Exposition. The model covers an area of about four acres and the scale on which the production is made is 1:600 horizontal and 1:150 vertical. It is within an oblong amphitheater, the water surface (or ocean level) being about 20 ft. below the spectators, who have thus a bird's-eye view of the canal and the adjacent territory.

Trains will be operated on the Panama R.R., and boats of all sizes and descriptions will be passed through the canal and locks. Along the channel will be the various range towers, buoys and light, which will be in operation, showing the same flashes as are actually used on the canal. Much ingenuity has been displayed in working out the details of operation. The boats are propelled through the lake and the canal by means of large magnets running underneath the floor on which the model is built. These magnets are mounted on trucks which travel along steel rails that serve also as conductors conveying current for energizing the magnets. The magnet trucks themselves are carried along by means of an endless steel cable.

The chief difficulty in the design has been the extremely sharp curves, the radius being as short as 18 in. in several instances. The longest single drive occurring in this magnet system is 480 ft. The vessels are equipped with iron cores which are about 2½ in. above the cores of the magnet beneath. Upon reaching a lock, the magnetic influence is removed, and at this point the boat is taken in tow by an electric locomotive for its passage through the lock. At the other end of the lock the boat is again picked up by one of the moving magnets.

One of the interesting features of the reproduction is the manner in which it is viewed. Completely surrounding the model, on top of the walls previously mentioned, is a continuous moving platform composed of sections hinged together for negotiating the corners. This has a seating capacity of 2000 people and moves at the low speed of 57 ft. per min., taking 20 min. to make the entire circuit. The spectators get on or off the platform at will. The platform is driven by means of stationary electric motors with pinions engaging a continuous rack beneath each section or car.

Each car is inclosed by a 2-in. pipe railing, and is equipped with chairs seating seven persons. Attached to each car is a telephone receiver delivering to the occupants a lecture on the objects immediately in front. The entire concourse is divided into zones, for each of which there is an individual lecture.

The exhibit is being installed (and will be operated throughout the Exposition period) by the L. E. Myers Co., engineers and contractors, of Chicago. The work is under the supervision of T. S. Johnston, chief engineer of the company.

Municipal Electric-Lighting Plants in California

A recent bulletin of the City Club of Berkeley, Calif., presents all the data available on the operation of the 17 municipal electric-lighting plants in California. This is summarized below. The club is agitating improved lighting service for Berkeley, and a special committee (J. T. Whittlesey, Consulting Engineer, Chairman) has made a survey of various services throughout the state.

Complete electric-supply plants, with generating stations, are operated by Alameda, Anaheim, Palo Alto and Pasadena; Healdsburg district obtains part of its current from a small hydro-electric station; Riverside, Glendale, Lodi, Ukiah, Biggs, Colton, Santa Clara, Gridley and Azusa purchase energy from public-utility corporations, but own the distributing system, light the streets and retail current. Burbank, Roseville and Redwood City are also in the latter class, but no data are available on operation.

Table I shows populations, incomes, expenses, profits, surpluses, bonds, rates, etc. The various figures have been adjusted to eliminate the effect of diversified schemes of accounting and to place all plants on a comparable

TABLE I—OPERATING DATA OF CALIFORNIA MUNICIPAL PLANTS; JUNE 30, 1912, TO JUNE 30, 1913

City	Population	Income from operating	Operating expense	Operating profit	Fixed charges	Surplus	% of income	Bonds outstanding	Rates: Minimum lighting bill	Rates: Cents per kw.-hr. Lighting	Rates: Cents per kw.-hr. Power	Cost of power, cents per kw.-hr.
Riverside	17,000	$143,984	$97,921	$46,063	$19,801	$26,262	18	$50,000	$0.50[2]	8 to 4	6 to 1.75	1.27[7] 1.01[8]
Pasadena	36,000	138,889	70,073	68,816	44,479	24,337	17	281,875	0.60[3]	5 to 3	4 to 1.5	1.31
Alameda	28,000	131,727	65,386	66,341	25,673	40,668	31	193,750	0.50	7 to 5	4 to 2	1.43
Palo Alto	5,000	44,780	27,336	17,444	12,989	4,455	10	85,826	1.00[4]	7.5 to 4	4	
Glendale	8,000	40,495	19,178	21,317	13,466	7,850	19	95,500	0.75	8 to 6	6 to 1.75	1.6[9]
Lodi	3,600	31,183	16,534	14,648	4,724	9,924	32	26,347	1.00	6 to 4	4	1.5[10]
Ukiah	3,500	18,858	14,687	4,171	2,047	2,123	11	11,700	...	10 to 5	4 to 0.75	1.6[11]
Colton	5,000	17,606	12,977	4,629	995	3,633	20	3,450	0.50	8 to 4	4 to 3	1.5[12]
Santa Clara	6,000	16,790	9,041	7,749	2,702	5,047	30	14,000	1.00[5]	10 to 4	8 to 3	1.8[13]
Gridley	1,250	9,715	5,533	4,182	2,375	1,807	18	13,500	...	10 to 2	10 to 2	1.5
Azusa	1,500	8,196	7,673	523	750	—277	—3	....	....	8	6	2.52[14]
Anaheim[1]	3,500	25,761	11,996	13,764	5,365	8,399	32	37,725	0.75	10	10 to 2.5[6]	...
Healdsburg[1]	4,000	16,990	8,417	8,573	5,168	3,405	20	30,000	0.50	10	5 to 3	2.25[15]
Biggs[1]	510	2,910	1,813	1,097	512	585	20	1,800	...	8	5	1.5

[1]Operated jointly with water supply; fixed charges apportioned and approximate. [2]Pumping 1.75; all lamps free. [3]Some free lamps. [4]1914; power 3c.; heating 2c. [5]1914; light 9c.; power 7c. [6]Operating and fixed charges on power generated, or average price for purchased energy. [7]Generated in steam stations of 310 kw.; now shut down. [8]Purchased; company has offered 0.85c. [9]Double rate for peak and off-peak power. [10]$5 per month per kilowatt demand. [11]$4 per hp. demand per month. [12]Now paying 0.9c. [13]Now paying 1.5c. [14]4c. for peak power; 2c. for off-peak. [15]Purchase price; generates 25% of supply.

TABLE II—LIGHTING BILLS IN THREE MUNICIPAL PLANTS AND BERKELEY (PRIVATE OWNERSHIP); AVERAGE COMPANY RATES

For year 1912-1913—

City	Minimum bill	Cents per kw.hr.	Bill for 25 kw.hr.	Bill for 50 kw.hr.	Bill for 100 kw.hr.	Bill for 250 kw.hr.
Riverside[1]	$0.50	8 to 4	$1.87	$3.75	$7.50	$15.75
Pasadena[2]	.60	5 to 3	1.25	2.50	5.00	11.75
Alameda	.50	7 to 5	1.75	3.50	7.00	15.00
Berkeley	1.00	7 to 3	1.75	3.50	6.50	14.50
Pacific Gas & Electric Co.	8	to 5	2.00	3.80	7.30	15.80
Great Western Power Co.	8	to 5	2.00	3.80	7.30	15.80
Western States Gas & Electric Co.[3]	6½	to 3¼	1.46	2.93	5.83	13.05
Northern Cal. Power Co.	7	to 3	1.70	2.90	6.20	13.70
Southern Cal. Edison Co.	8	to 3	2.00	4.00	8.00	18.50
Los Angeles	6	to 2½	1.50	3.00	6.00	14.62

[1]Allowance ½c. for free lamps. Purchased current.
[2]Some free lamps. No allowance.
[3]Includes 10% cut for Stockton.

TABLE III—CHARGES FOR STREET LIGHTING IN REPRESENTATIVE CALIFORNIA CITIES

	Arc	Incandescent
Municipal Plants—		
Riverside	2.12c. per kw.-hr.	2.12c. per kw.-hr.
Pasadena	$60.00 per year.	$12 per year per 50-watt unit. $24 per year per 100-watt unit.
Alameda	3.12c. per kw.-hr.	3.12c. per kw.-hr.
Palo Alto	5c. per kw.-hr.	5c. per kw.-hr.
Private Plants—		
San Francisco	$69.35 per year.	$62 per year per 210-watt unit.
Oakland	$68.50 per year.	$27 per year per 100-watt unit.
Los Angeles	$75.60 per year.	4c. per kw.-hr., no renewals.
Sacramento	$66.00 per year.	1.5c. per kw.-hr.
Stockton	$72.00 per year.	$6.84 per year per 50-watt unit.
Redlands	$54.00 per year.	$10.20 per year per 200-watt unit.

basis. The principal eliminated differences were in the items of public lighting, miscellaneous income and fixed charges. Four towns make no charge for street lighting and several charge too little; for these, additions have been made. Where miscellaneous income (sale of material, wiring, etc.) is large, it has not been included. Several towns make no charge for depreciation; some charge bond redemption in annual cost; some charge eliminated taxes. In Table I, fixed charges cover (1) interest on outstanding bonds; (2) annual bond redemption; (3) depreciation. A very apparent need is the adoption of a uniform system of accounts for municipal utilities.

Personal inspection of several plants shows the following condition; seven good, four fair, four poor; yet a small extra annual expenditure would keep them all good and the profits shown are sufficient for this. The trouble arises in small towns which cannot afford competent men. A solution was secured by the towns of Burbank and Glendale whereby the Glendale superintendent built the Burbank distributing system and maintains it, the latter town paying for labor, materials and part of the superintendent's salary.

The number of men employed was generally found to be too small—the result of a desire to show large profits and to prevent political criticism.

The plants are reported, with one unimportant exception, to be meeting all charges, paying off indebtedness, and earning a surplus for extensions and improvements. Large surplus profits and small amounts of outstanding bonds are generally seen. The rates could be reduced by the percentage of surplus to income and still have all charges met.

Table II gives a comparison of lighting bills in three of the larger municipal plants with Berkeley (Pacific Gas & Electric Co.) and with general rates filed by various power companies. Table III gives some representative prices for street lighting under private and public operation.

TABLE IV—DETAILED STATEMENTS OF MUNICIPAL ELECTRIC PLANTS, PASADENA AND ALAMEDA

GENERAL DATA

	Pasadena	Alameda
Population, estimated, 1913	36,000	28,000
Total assessed valuation	$54,342,815	$20,971,561
Bonded debt	3,555,000	713,925
Bonds outstanding on electric plant	281,875	193,750
Area (sq. mile)	11.2	7.4
Number of consumers	4,777	4,308
Miles of pole lines	150	75
Capacity of power station (kw.) (Steam engine and turbine, condensing.)	3,000	2,550
Total current generated (kw.-hr.)	4,022,230	3,611,555
Total current sold, light and power (kw.-hr.)	2,284,043	1,589,920
Total current street lighting (kw.-hr.)	870,840	1,080,916

RATES

Average rate for current sold—		
Lighting (per kw.-hr.)	4.76c.	6.99c.
Power (per kw.-hr.)	2.62c.	3.90c.
Total private use (per kw.-hr.)	4.08c.	6.26c.
Charge to city for street lighting:		
Arc lamps, $60.		
Incandescent, 40 cp., $12; 80 cp., $24, and 3c. per kw.-hr., plus lamp renewals		2¼c.

REPORT FOR YEAR ENDING JUNE 30, 1913

Operation Account

Income—		
Street lighting	$45,711.93	$33,707.80
Commercial light and power	93,177.48	99,556.30
Miscellaneous	.....	4,839.10
	$138,889.41	$138,103.20
Less discounts and bad debts	.....	2,476.60
Total	$138,889.41	$135,626.60
Expenses—		
Manufacturing	$36,840.82	$35,771.71
Distribution:		
Public lighting	5,322.54	
Commercial pole lines	11,825.76	22,492.51
General	16,084.33	7,122.07
Total	$70,073.45	$65,386.29
Operating profit	$68 815.96	$70,240.31
Fixed charges—		
Total interest on plant value	$20,728.54	$10,815.00
Depreciation	24,529.33	16,819.00
Taxes	.....	2,030.00
Total	$45,257.87	$29,664.00
Surplus	$23,558.09	$40,576.31
Unit costs—		
Generation—Operating (per kw.-hr.)	0.92c.	0.99c.
Fixed charge (per kw.-hr.)	0.40c.	0.42c.
	1.32c.	1.41c.
Production per unit sold (per kw.-hr.)	1.67c.	1.90c.
Distribution—Operating (per kw.-hr.)	0.55c.	1.11c.
Fixed charges (per kw.-hr.)	0.93c.	0.55c.
	1.48c.	1.66c.
General expense (per kw.hr.)	0.50c.	.....
Total cost per kw.-hr. sold	3.65c.	3.56c.

Capital Account

Assets—		
Property	$495,055.38	$300,244.63
Balance from capital account	26,467.89	.....
Inventories	15,237.58	2,163.33
Personal property	9,409.60	.....
Accounts receivable	16,471,89	141,540.34
Cash	5,125.90	724.93
Advance and suspense	.....	66,371.71
Total	$567,768.24	$511,044.94
Liabilities—		
Funded indebtedness	$281,875.00	$193,750.00
Contribution from premium on bonds	3,836.43	.....
Contribution from taxes	182,976.06	.....
Balance	26,467.89	.....
Accounts payable	1,246.88	8,065.19
Net balance of interest reserve	29,716.82	.....
Gain in operating, year, 1913	23,558.09	.....
Surplus	18,091.07	307,345.75
Deposits	.....	1,884.00
Total	$567,768.24	$511,044.94

The utility corporations have a plant capacity (steam and water) of nearly a million horsepower and they distribute over thousands of miles of line. Some six million horsepower is available in the streams of the state and of this 1½ million has been taken up. Another three million is capable of economic development. This makes it feasible for small cities to own distribution lines and purchase current at low rates.

Terminal Improvements of the Canadian Pacific Railway at Vancouver, B. C.*

On account of the rapid growth of traffic at the Vancouver terminal of the Canadian Pacific Ry. in British Columbia, it became necessary about two years ago to provide for increased facilities both for handling passenger and freight business. The transcontinental trains connect not only with steamship lines controlled by the railway but with other lines which reach many points along the coast of British Columbia and the United States and transpacific points. The interchange of traffic between railway and steamers as well as between the city of Vancouver and other points necessitated somewhat unusual terminal provisions.

A general plan of the Vancouver terminal situation and the relation between the railway passenger station, steamship wharves, viaducts and local freight yard is shown in Fig. 1. It will be noted that the passenger station is located at the foot of Granville St., one of the principal thoroughfares in the city, and that this street has been extended over the passenger and freight tracks to a new steamship pier. Two city blocks to the west, at Burrard St. (not shown in Fig. 1) another viaduct has been constructed over the tracks to afford access to the transpacific steamship pier built in 1908 and which has been extended out to the harbor line. This extension was made to provide for the larger steamships which were put into service within the last two years.

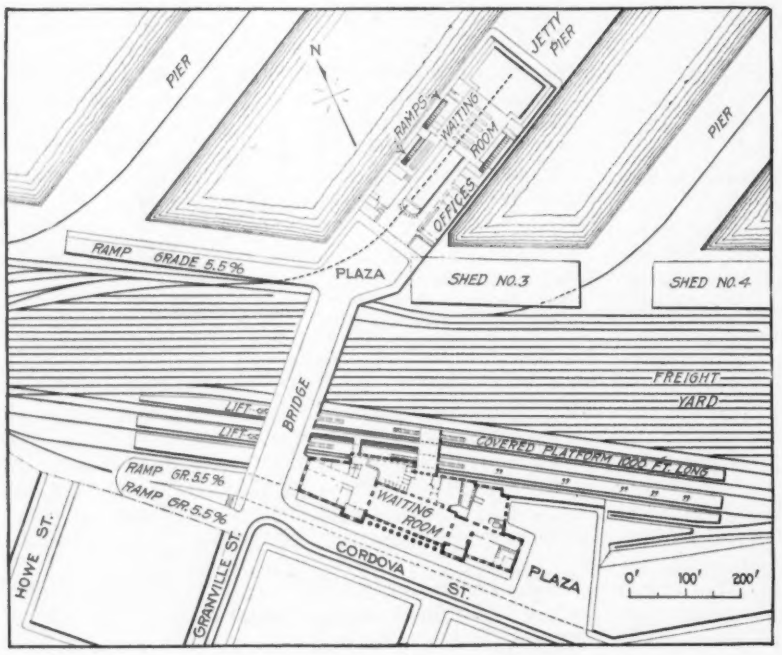


Fig. 1. Layout of Passenger Terminal and Ocean Pier, Canadian Pacific Ry., Vancouver

The site of the old passenger station was directly at the foot of Granville St. and the only means of access to the steamship piers before the improvements were made was by way of a grade crossing to the west of the old station. This grade crossing naturally was a source of danger and delay and in the new plan the freight yard was rearranged with connections to reach the present steamship piers as well as those which might be constructed at some time in the future when business required.

The passenger layout provides four through tracks raised about 5 ft. above the old grade in order to reduce somewhat the vertical distance between the street level and tracks which existed under the old arrangement. Provision has been made for an extension of the track layout by leaving room for additional tracks to the north over the site occupied by freight tracks, the station building facilities being adequate to serve several times the number of passenger tracks which are built under the present plan.

Railway Passenger Station

Granville St. and Cordova St. were about 35 ft. above the old level of the tracks. Under the new scheme there is a difference of about 30 ft., this condition necessitating the use of a two-level station with the principal public rooms on the street floor and railway facilities for baggage, express, etc., on the track level below. The plan also lends itself to providing a convenient means of access to the train platforms and shelters by a bridge over the tracks; also independent exits are provided so that passengers may go directly to the street without passing through the station. Electrically operated baggage lifts are provided by which baggage may be raised from the platform level to Granville St. extension and thence carried to the steamship pier.

On the ground or street level of the station are found the general waiting room, ticket offices, lunch room, women's waiting room, smoking room and baggage checking room all conveniently located with relation to each other and with generous allowance of space for lobbies and corridors. The general waiting hall is 143x56 ft., not including the east and west lobbies each of which measures 46x28 ft. The women's waiting room is 46x36 ft. and the smoking room 46x36 ft. On this floor is also located the lunch room with its service pantry. The kitchen and refrigerating rooms are placed on a mezzanine floor below the street level. On the track floor are the baggage, mail and express rooms, also rooms for Canadian and U. S. Customs, warerooms for the news and dining car departments and the power plant where steam is generated for car heating and other service facilities. Between the station building and Cordova St. at the lower level is a large paved area used for baggage, mail and express trucks, to which access from the street is had by a ramp descending on easy grades to the west of the station building from Cordova St.

The passenger station is a steel-frame structure, with pressed brick face and Indiana limestone trim (Fig. 2). Above the ground floor are three floors devoted to offices for the use of the railway company. A large interior court

*From information furnished by Westinghouse Church Kerr & Co., 37 Wall St., New York City.

affords natural lighting for the general waiting room and also for the office rooms which are in the interior of the structure.

The track arrangement provides two tracks for inbound trains and two tracks for outbound trains, with separate platforms. There is a platform adjoining the station used for baggage, mail and express only. While Vancouver is the end of the line, the station is arranged

FIG. 2. CORDOVA ST. FRONT OF NEW CANADIAN PACIFIC TERMINAL AT VANCOUVER

as a through station in order to get the best use of the tracks and avoid blocking the approaches when trains are backed out preparatory to shifting to the storage yards. Incoming trains proceed westerly and back out over the thoroughfare in the freight yard, leaving the station tracks clear of all shifting movements.

STEAMSHIP PIER

The extension of Granville St. by viaduct over the tracks affords access to the upper level of the new steamship pier. This viaduct is 80 ft. in width and is enlarged in front of the pier station to provide ample space for public and private vehicles. Baggage and freight are received at the pier on the lower level to which access is had by ramps leading from Granville St. and Burrard St. Viaducts.

The substructure of the pier is built largely of creosoted timber and has connected with it a number of unusual features. Teredo are very active in the waters of the Burrard inlet and untreated timber cannot safely be used for more than two years where called upon to bear heavy loads. The depth of water at high tide at the outer end of the pier prior to construction was over 60 ft., with a rather soft material in the bottom necessitating very long piles. About 3000 piles were driven in the substructure, ranging in length from 85 to 110 ft. The harbor was filled in at the site of the pier as high as practicable without interfering with the draft of vessels which would use the pier, and the piling was then driven through the filling. The substructure is well braced below the low-water line and the filling referred to adds additional stiffness to the structure. Fenders of large logs chained together afford ample protection to the pier and distribute evenly throughout the structure any shock which may occur from vessels striking the pier.

A railway track depressed so as to bring the floor of the cars about even with the pier floor is carried through the center of the pier. The decking of the pier is made of Australian hardwood, which has been found to give the best wearing results with the class of traffic and atmospheric conditions existing in Vancouver. The superstructure is slow-burning timber construction, covered with wood sheathing. The waiting hall is 83x96 ft., separate rooms being provided for ladies' rest room, smoking rooms, and the immigration and customs departments for both Canada and the United States. There is a promenade, overlooking the harbor, and leading from the waiting room on the outer end of the pier, over the one-story freight structure. As one enters from the viaduct, the ticket office, parcel room and baggage checking room are conveniently reached on a concourse leading to the main waiting room.

Access to the boats from the upper level is afforded by means of ramps leading from the concourse on an easy grade to the landing on which the gang planks are placed. This landing is adjustable for different stages of the tide, which has a range of about 16 ft. Passengers coming from the boats go through the customs examining rooms, or, where such examination is not necessary, may be diverted directly into the concourse. On the lower level, which is used for baggage, express and freight, there are provided Barlow lifts on each side of the pier to match the vessel ports. These are adjustable elevators which may be used as sloping gangways or raised and lowered similarly to an elevator; they are 10x18 ft. in area, holding several trucks at one time.

PERSONNEL

The general designs and layout of the entire work were prepared and the construction of the terminal buildings and equipment was performed by Westinghouse

FIG. 3. STREET ELEVATION OF CANADIAN PACIFIC STEAMSHIP PIER, VANCOUVER

Church Kerr & Co., Montreal and New York, under the general direction of the Engineering Department of the Canadian Pacific Ry., J. G. Sullivan, Chief Engineer. Messrs. Barott, Blackader & Webster of Montreal were architects for the passenger station building. Work was begun early in 1912 and the station and pier were opened to the public in July, 1914.

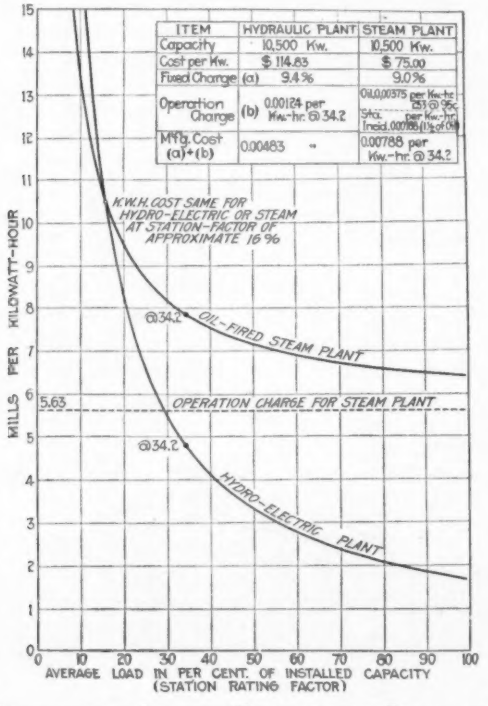
Topographic Surveys completed by the United States Geological Survey in the year ending June 30, 1914, covered 23,098 sq.mi. The total area topographically surveyed in the United States to that date was 1,197,782 sq.mi., or 39.6% of the entire country.

The Possibilities of Hydro-Electric Power in the Pacific Northwest

By Geo. H. Moore*

The oft-debated questions of the economy of steam and water power find an answer in the Pacific Northwest states that must interest engineers in other parts of the country; the immense preponderance of water-power drive throughout the Pacific states and the possibilities of hydraulic development there admit of but one conclusion—the local superiority of water over steam.

In spite of the recent statement of J. A. Britton, General Manager of the Pacific Gas & Electric Co., that "steam will become a cheaper prime mover for the generation of electrical energy than the falling water of streams," yet central-station managers in the heart of the California oil fields still authorize hydro-electric developments which



Comparative Costs of Energy from Steam and Hydro-Electric Power Stations near Puget Sound

bring pioneer problems in construction, generation and transmission. Whatever relation may exist elsewhere about the United States, there is little room for doubt as to the economic standing of the two prime movers on the Pacific Coast.

A glance at the accompanying chart, worked out for Puget Sound conditions some years ago, may be of interest. This discloses the vital importance of average use of installed capacity. Thus, if a further statement of Mr. Britton, that "the load factor has grown from 12% in the distant past to a figure of 70% at the present," refers to this station rating factor instead of an average-to-maximum output ratio, the conclusion is self-evident. This is attested by Mr. Britton's continuation, that "electrochemical processes will perhaps change the tendency, so that hydro-electric energy will continue to be below steam energy in cost of production." Since the highest station-rating factor in the largest electrochemical industries is now about 70% and since this factor for most of the generating stations of the Coast is as high as 70% to 40% probably, the curve shown throws considerable light on the ceaseless interest in water-power development even where oil is cheapest, rainfall least and surface evaporation highest for the Western Slope.

If this condition prevails where evaporation and precipitation are so nearly matched as to cause engineers to rescue run-off by the ingenious expedient of sub-surface storage, then the superiority of water power certainly is assured in the section further north and especially in the regions tributary to Puget Sound. Right here, the precipitation is a maximum for the United States, the run-off rises to a high percentage of rainfall, and evaporation is negligible—even for reservoirs of considerable area.

In connection with such a statement, one should review such cases as the pseudo-paradox at Snoqualmie Falls. There, a mean annual rainfall of 59 in. is observed but the run-off corresponds to an average depth of more than 80 in. over the whole 440 sq.mi. of catchment area. The Skagit River, a huge factor in the future hydro-electric developments of the Northwest, has 1100 sq.mi. of tributary watershed and discharges the yearly equivalent of over 6½ ft. of water over the whole basin.

These two examples are not isolated ones. The discharge of streams rising in the Olympics is only just beginning to be studied and new high figures will be set. In the reports of the U. S. Bureau of Soils, one station (Quinault) the yearly average rainfall is upward of 140 in., with a maximum of 157.

There is thus no reason for surprise in the fact that of the odd 90,000-kw. capacity in plants supplying Seattle and its contingent territory, less than one quarter is in steam plants. Even this employment of steam is promoted by the lack of long-distance transmission lines in the coast portions of the Northwest and reliance on steam auxiliaries as emergency reserves in spite of an operating cost per energy unit double that of the connected water-power stations.

The power developments thus far made in the Northwest are only sturdy pioneers of an army to follow. One proposed development on the Skagit River will exceed everything so far constructed; a three-year study of this stream shows a mean annual flow of 5300 cu.ft. per sec., which, with the available head of 600 ft., would produce a continuous output of 200,000 kw. This would permit, with a station-rating factor of 50% and proper daily storage, an installed capacity of 400,000 kw. This project is within 100 miles transmission distance of Seattle.

Only three plants are taking toll of the potential energy in the snows on Mt. Rainier. Two belong to the Puget Sound consolidation; one has 14,000-kw. capacity in machines installed at Electron, while the other at Lake Tapps has an initial development of 20,000 kw., though 60,000 kw. is projected. The third plant is the 20,000-kw. Tacoma municipal station on the Nisqually at La Grande.

The sheer drop of 270 ft. at Snoqualmie Falls was quite naturally one of the first to be utilized; the initial develop-

*City Hydrographer, Seattle, Wash.

ment put a 11,000-kw. station in the rock-hewn cavity there and this has been supplemented by a 9000-kw. plant outside but taking water from the same source. The 11,000-kw. installation of the Seattle municipal system at Cedar Lake completes the roll of hydraulic plants supplying the bulk of power in the Puget Sound country. These are all infant industries growing fast. That is true also of the network of the Washington Water Power Co., radiating from Spokane; it applies to the developments of the Portland Ry., Light & Power Co., in and about Portland, and to the various installations in British Columbia—particularly those supplying Victoria and Vancouver. All have the three essentials for ultimate success—the head, the water and the market.

Water-Works Improvements at San Diego, Calif.

Improvements to the San Diego water-supply now in progress include a small diversion dam, an open conduit of concrete seven miles long on which there are several drops and a metal flume, and also a small settling reservoir at the end of the conduit. Besides these improvements in the old gravity source of supply there was put in operation on Dec. 31, 1914, a new well and pumping system to supply a part of the city. Some of the more interesting features of both pieces of work will be described.

The New Conduit and Accessories

Diversion Dam—At the junction of Hauser Creek with the Cottonwood River, about 1½ mi. below the

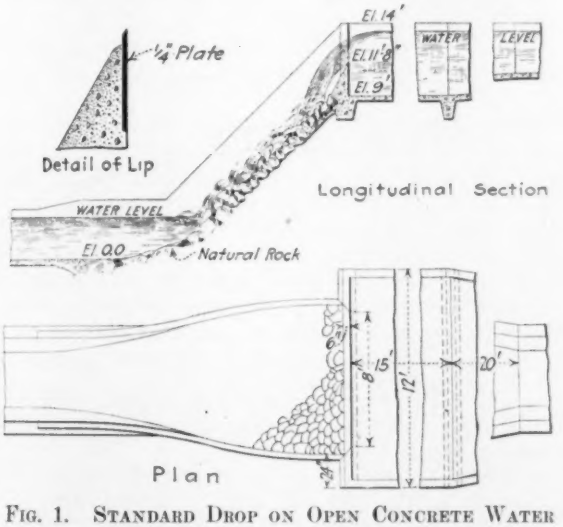


Fig. 1. Standard Drop on Open Concrete Water Conduit, San Diego, Calif.

Morena Dam of the San Diego water-works, a dam 8 ft. high and 75 ft. long has been built to divert water into the new conduit.* The water from the dam flows directly into the conduit over a weir 8 ft. long and 3 ft. deep, designed to pass 70 cu.ft. per sec., the conduit capacity.

Conduit—The conduit is 4 ft. 10 in. wide on top, 3 ft. 2 in. wide on the bottom and 2 ft. 11 in. deep. It is lined on the sides and bottom with 4 in. of concrete. The velocity in some places is 10 ft. per sec. One of the drops is shown by Fig. 1. The conduit is built in sections 16 ft. long, separated by tarred paper. Each joint is supported by a rib 8 in. long and 4 in. deep, separated from the conduit by a thick coating of asphaltum.

Steel Flume—Details of a semicircular steel flume on a wooden trestle are shown by Fig. 2.

Settling Basin—At the lower end of the conduit is a settling basin or sand catcher 70 ft. wide, 100 ft. long and 7 ft. deep, with a baffle wall 3 ft. high running its entire length to intercept the sand. A driveway gives access to the basin for removing sand.

Mission Valley Driven-Well and Pumping System

On Dec. 31, 1914, a new well system was put in use. A pump in each well delivers water to a conduit leading to

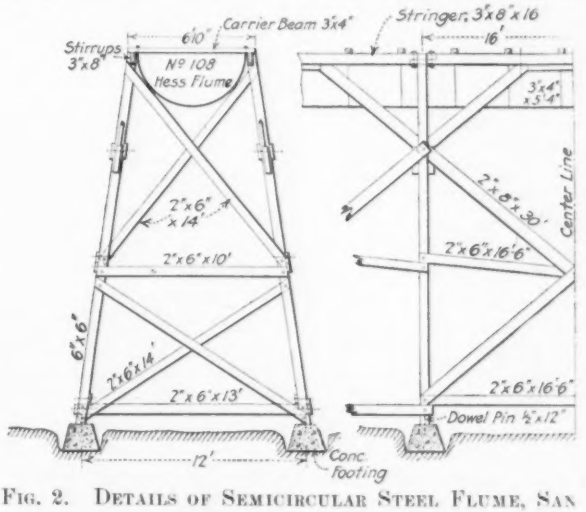


Fig. 2. Details of Semicircular Steel Flume, San Diego Water-Works

(The trestle shown is typical for 12-ft. heights and greater. All joints were bolted with ⅝-in. machined bolts, with a ¼-in. wrought-iron washer on each end)

a 5,000,000-gal. high-lift pumping station, which forces water through another conduit to a reservoir. The wells are sunk in the sands of the San Diego River and the water is delivered to the University Heights Reservoir, 335 ft. above the river and 385 ft. above sea level.

Driven Wells—There are 13 wells, 12 in. in diameter, with an average depth of 65 ft. The lower part of each casing is perforated with ⅜x8-in. slots. In each well is a two-stage pump with a 10-hp. belted motor, except for one direct-connected unit.

Collecting System—The pumps discharge into concrete standpipes, 3 ft. in diameter, from which a 10-in. steel pipe leads to a sand catcher in the main collector. This collector is from 12 to 24 in. in diameter and discharges over a measuring weir into two concrete sumps, with a combined capacity of 165,000 gal.

High-Lift Pumps—Two four-stage, direct-connected Platt Iron Works turbine pumps, each driven by a 250-hp. motor, lift the water from the sumps and force it through 7900 ft. of 16-in. cast-iron pipe to the reservoir, which is 335 ft. above the river bed. The pumps have a rated capacity of 2,750,000 gal. each and a combined capacity of 5,000,000 gal.

Herbert R. Fay is Superintendent of the Department of Water, Pueblo Lands and Forestry at San Diego.

*The Morena Dam was described in "Engineering News," June 12, 1913. Other articles on the five dams and on other features of the San Diego water-supply may be found in "Engineering News," April 7, 1904, Nov. 26, 1908, and Dec. 30, 1909

A Plan for Municipal Irrigation from the Los Angeles Aqueduct

By Burt A. Heinly*

SYNOPSIS—The surplus waters of the Los Angeles Aqueduct will be distributed by a number of main conduits and a vast network of smaller pipe to irrigate 87,090 acres of land. To secure the water, the territory has to be annexed to Los Angeles. As the irrigated area is built up with houses the irrigation system will change into a city water-works system. There will be 317 mi. of riveted steel mains from 54 to 8 in. in diameter, under a head of from 40 to 300 ft., besides the main conduit. Storage reservoirs also form a part of the system. The estimated cost of the whole project is $4,472,674, or $50.90 per acre. Of this $17.42 will be borne by the city and $33.58 by the owners of the land to be irrigated.

A plan for the use of the surplus waters of the Los Angeles Aqueduct has at last been prepared, by far the larger of the proposed irrigation districts has been formed and on Nov. 10, 1914, the district voted $2,606,000 of bonds to carry out the project. By this action the utilization of something over one-half the flow of the Aqueduct seems assured. The proposed construction is second only in magnitude to the building of the Aqueduct. The irrigation system, comprising a total of 87,090 acres, compares favorably in size with a number of similar projects of the United States Government. So far as the writer knows, this is the first irrigation enterprise to be undertaken by a municipality and the only irrigation system of any size where the water is supplied under pressure.†

Geographical Position

The two irrigation districts stretch nearly thirty miles north and northwest from the present city limits of Los Angeles to include the major part of the arable land of the San Fernando Valley. This is exclusive of the three or four incorporated towns of the valley, to which Los Angeles is prepared to furnish a water-supply.

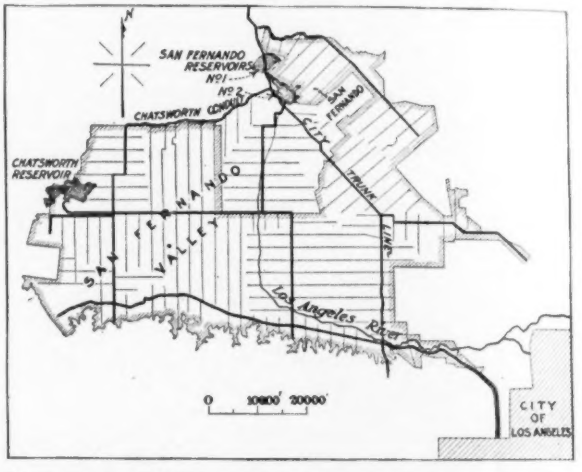
The land to be irrigated ranges from sandy loam to clay and much of it is adapted to the growth of southern California's most valuable product, citrus fruits. The 87,090 acres comprise two political divisions, the Mission District of 11,010 acres, and the San Fernando Irrigation District No. 3 of 76,080 acres. Geographically and for purposes of service, the area includes eight districts, ranging from 4800 acres to 13,000 acres in extent.

Financial Details

By the terms of agreement with the land owners, Los Angeles has agreed to defray the major cost of the Glendale Trunk Line, the Chatsworth Conduit and the Chatsworth Reservoir. (See map.) The city's estimated expenditure is $1,496,959. The land owners for their part have agreed to pay a proportional cost of the City Trunk Line now built and in operation, and of the proposed Cahuenga and Glendale Trunk lines, and build all other mains and laterals. By annexation, the whole property will automatically come under the control and operation of the municipality. The estimated cost of the whole work is $4,472,674. Of this, the estimate for the Mission District is $369,715 and for the San Fernando Irrigation District No. 3 $2,606,000. This latter amount, as above stated, was authorized by the district on Nov. 10, by a vote of 739 for and only 12 against.

Plan of Supply

The San Fernando Valley may be likened to an ill shaped bowl, slightly tipped in the direction of a lip



Map of the San Fernando Valley, Showing Outline of the Plan for Municipal Irrigation from the Los Angeles Aqueduct

which points toward the city of Los Angeles. (See map.) The lowest elevation of the proposed irrigation system is approximately 600 ft. above sea level. From there the land rises by gentle slope to the foothills encompassing it on the north, south and west. From the outlet of the Aqueduct, at El. 1461 ft. above sea level, a trunk line of tunnel and steel pipe will irrigate an area of 8960 acres, the highest elevation to be reached being 1400 ft. This district, on account of its high elevation, will be operated independently of the remaining area. Also, at El. 1150, and leading off from the conduit forming a part of the City Trunk Line, one mile above the Lower San Fernando Reservoir, a conduit, the Chatsworth, will extend southwestward 10.3 mi., watering a large acreage beneath it during the irrigation season and in the rainy season storing its flow in the Chatsworth Reservoir. This basin, of 25,000 acre-ft., situated on the western rim of the valley, will irrigate the main floor of the valley.

*645 South Olive St., Los Angeles, Calif.

†To make this possible the Legislature passed the Shenk Act, which permits the localities included to form themselves into districts and vote bonds. These districts are authorized to incorporate themselves into the municipality of Los Angeles, which then becomes the builder, owner and operator of the works. To carry out the plan Los Angeles will have to annex a territory considerably larger than its present area. Previous articles on the utilization of the surplus waters of the Los Angeles Aqueduct have appeared in "Engineering News" of Dec. 29, 1910, and March 3, 1913.

The south side of the valley at El. 1000 ft., tapering off to 850 ft. in the southeast corner of the district, will be watered from trunk lines leading across the valley from the Chatsworth Conduit, the Lower San Fernando Reservoir and the City Trunk Line. The east end of the district will be partially supplied from the City Trunk Line, from which Los Angeles procures her Aqueduct supply and which was designed and built with this end in view.

The Chatsworth Reservoir as well as the Lower San Fernando Reservoir will have a twofold purpose to perform, for these reservoirs insure the storage of the water from the operation of the Aqueduct during the winter months at a time when there will be continuous operation of the Aqueduct at normal flow for the development of hydro-electric energy.

From the main trunk lines, smaller lines will branch off so that the entire district of 87,090 acres will be traversed by a network of laterals spaced not farther than one-half mile apart, which makes provision that no acreage is farther than a maximum of 1320 ft. from a main of at least 8 in. diameter. With the exception of a few instances, all lines will follow public roads, the owners of property taking the water from the distribution system being called upon to provide their individual property irrigation system.

Design

The Chatsworth Conduit is designed for a flow of 7500 miner's inches, or a little more than one-third the rated flow of the Aqueduct, to which it will be very similar in design and structure. The classification comprises 34,445 ft. of covered conduit with grades ranging from 0.001 to 0.0035; 4240 ft. of steel flumes with a grade of 0.001, and 20,440 ft. of 52-in. pipe of ¼-in. steel, having a grade of 0.0095 and emptying into the Chatsworth Reservoir.

With one minor exception, the remainder of the system is to consist of riveted steel pipe ranging from 54 in. diameter for the largest trunk lines down to 8 in. diameter for the smallest laterals. Both mains and laterals have been figured to deliver a continuous flow of one miner's inch to five acres. As the irrigation season comprises approximately 240 days, the duty is thus 1 in. to 7½ acres. This duty was arrived at by a survey of southern California for the practice in the irrigation of citrus orchards. At the same time, tests of water consumption which were made in the city of Los Angeles for residence districts worked out to the same figure so that wherever and whenever the district becomes of a suburban type, the transition from irrigation to domestic use entails no change in the distribution or supply system.

The mains are designed to supply the quantities stated above at an irrigating head of 48 in. at any desired point on the system. Assuming a velocity of 2.75 ft. per sec. in the 8-in. laterals, the line allotment for a 10-acre tract would be 30 hours each month.

Allotment of water to irrigators on the above basis expressed in terms of acre-feet provides for 1.93 acre-ft. per year per acre, and with an average annual rainfall of 15.7 in. in this region, it will be seen that except in seasons of drought the land is assured of an equivalent of 39 in. of rainfall per annum.

The construction will entail the building of 317 mi. of mains, requiring 25,719 tons of steel. For the 8-in. laterals, No. 12 gage ($^7/_{64}$-in.) steel will be used and for mains from 12 to 18 in. diameter, No. 10 gage ($^9/_{64}$-in.) metal, while for mains of larger size, the thickness of steel has been figured on the basis of a safe working stress of 15,000 lb. per sq.in., net section. Riveting, on the large mains, will be the same as on the San Fernando Siphon of the City Trunk Line, described in ENGINEERING NEWS of May 22, 1914. There will be a cover of 3 ft. above the top of the pipe. Water will be supplied under a head of from 40 to over 300 ft.

Excepting where heavy pressures require, the regular standard water-works gate in use on the Los Angeles system, designed for a working pressure of 200 lb. per sq.in., will be installed. On the 8-in. and 10-in. mains, full-size gates will be used, at half-mile intervals. On mains from 14 to 20 in. diameter, a gate equal in valve area to one-half the area of the pipe will be used, spaced one mile apart; on larger mains, gates designed in the same proportion but at two-mile intervals will be used.

Estimates of Cost

The estimates of cost have been prepared on the basis of 5c. per lb. for the steel in place, with fittings estimated of 2½%, and 10% for gates, engineering and contingencies. The plans were prepared before the opening of the Panama Canal, and reduction in price on cast-iron pipe by all-water shipment has amounted to $3 per ton since the canal opened, with the possibility of a still further discount as soon as shippers have accustomed themselves to the new conditions. Unless unforeseen circumstances arise to greatly advance the base rate of materials, the estimate is a fair one.

Construction

The estimate of time for completion is placed at approximately two years from the date of opening construction, and this depends only on the availability of funds. Large quantities of construction equipment, as salvage from the construction of the Aqueduct and the City Trunk Line, have been assembled at warehouses at the Lower San Fernando damsite and 500 men fully equipped could be placed in the field within 10 days after the word to begun work is given. Steel deliveries would be the principal item of delay, but with present and prospective conditions of the market and division of contracts, progress would be unlikely to meet with serious delay on this score. On mains 54 to 60 in. where nesting is not possible, Pacific Coast factories are in a position to underbid Eastern competitors.

Acreage Costs and Payments

For the total 87,090 acres, the average cost, under the estimates of William Mulholland, Chief Engineer of the Los Angeles Department of Public Service, amounts to $50.90 per acre. Of this, the part borne by Los Angeles in the building of trunk lines and the Chatsworth Reservoir amounts to $17.42 per acre, so that the net cost to the land owner of bringing the water to his land, or within a maximum of 1342 ft. from each acre, amounts to $33.58.

Under the Shenk Act, however, the cost is not based on acreage, but is made proportional to the assessed valuation of the land. The bonds recently voted by San Fernando Irrigation District No. 3 and other bonds subsequently to be voted will run for 40 years, payments of the

sinking fund not commencing until 10 years from date of issue and then being payable in 30 annual installments. This plan was followed for two reasons: (1) Because it gives opportunity for the construction of the work and the provision for making it pay its own way, and (2) (and of equal importance) the payments are made proportional to the value received. In the east end of the valley, being nearer to Los Angeles and under partial irrigation from pumpage, the land has reached a fairly high state of cultivation with an equivalently high assessment. It is true that this more improved section must pay more than its proportional share of interest charges for the first decade, but by the end of that period the entire valley should be under irrigation, and the northern and western portions now thinly populated and under dry farming will have reached a condition of prosperity where the burden of payments of the principal will be much more equitably adjusted than is now possible.

Cost of Irrigation and Water Rights

The city has set a rate for irrigation of 1c. per miner's inch per hour, which, on the basis of 1 in. to 7½ acres for a period of 240 days, amounts to $11.68 per annum—a cost believed to be cheaper than for pumpage in the valley.

The most troublesome subject before the California courts is the question of water rights and in the present instance it is disposed of once for all in this way. The city has provided as the first requisite for the use of the water incorporation within its own limits. No water rights *per se* are given to the land. The irrigation user upon application and payment for the use of the water, to all intents and purposes stands in the position of a Los Angeles property owner who has paid for a tap from the city system and the water cannot be taken from the land so long as the rules of the Bureau of Water-Works and Supply are complied with. The water right is therefore one in fact and it has been accepted as such by the prospective water users of the district.

Immediate Market

Los Angeles during the past summer has stood in the unusual position of a city which has long been threatened with a water famine but which now has a supply amounting to a large surplus, yet because of political conditions and lack of distribution facilities is unable to dispose of it.

The proscription of a year ago that only territory within the city limits could use the water cut off an immediate market along the City Trunk Line, but effectively guarded the city against the plans of corporate interests who were prepared to contest the city in the possession of her water rights. With annexation accomplished within the next few months, the City Trunk Line should be available for the irrigation of a strip of several miles on each side of it during the summer of 1915. In addition, a temporary open, unlined ditch, taking its supply from the Lower San Fernando Reservoir, ready for storage about Jan. 1, will be carried for 7 mi. southwesterly toward the Chatsworth Reservoir. Beginning at an elevation of 950 ft., and with a capacity of 7500 miner's inches, it is anticipated by this means that 10,000 acres can be placed under the water during the coming irrigation season. Upon completion of the permanent system, this ditch will be abandoned.

The Snoqualmie Tunnel; C., M. & St. P. Ry.

The Puget Sound extension of the Chicago, Milwaukee & St. Paul Ry. crosses the summit of the Cascade Range about 60 miles east of Seattle, Wash., and the original plans called for a summit tunnel. In order to expedite the completion of the line through to the Pacific Coast, however, it was constructed with an open high-level line through the Snoqualmie Pass, and with this the road was ready for traffic in 1908. The operating troubles over this summit were serious, due to the heavy grades and the open high-level line over the Cascades (where snow conditions are exceptionally severe). Consequently, surveys for the tunnel were soon started.

The high-grade or open-pass line extends north and northwest from Keechelus, Wash., to the summit at Laconia (4.75 miles) with a grade of 2.2% and then southwest on a descending grade of 2.75% to Rockdale (4.4 miles). Its maximum curves are of 8°, and its summit is 3005.7 ft. above sea level.

The low-grade tunnel line or cutoff runs north from Keechelus to the east portal, and then due west to Rockdale, at the west end of the tunnel, 4.5 miles. This line saves 3.75 miles in distance (or about 40% of the distance between Keechelus and Rockdale), 444 ft. in rise and fall, and 1240° in curvature. It will enable westbound trains to dispense with the present helper service. Heavy eastbound trains will require only one instead of two helper engines, this helper service being necessitated by a 20-mile grade of 1.75% from Cedar Falls to Rockdale.

The tunnel is 11,886 ft. long, with a summit elevation of 2556 ft. at 2000 ft. from the east portal. From the east end it has an ascending grade of 0.1%, followed by a descending grade of 0.4%. The tunnel is on tangent, but a 6° curve begins just inside the east end and a 3° curve inside the west end.

Work on the tunnel was commenced early in 1912, with the idea of extending the construction over several years. The severe snow troubles on the open line during the winter of 1912-13 made it evident that the low-grade tunnel line would have to be completed as soon as possible, and steps were taken to push the work vigorously.

The headings met on Aug. 4, 1914, but a slide about 1800 ft. from the east portal made it necessary to hole through from the west heading, and as the east and west ends had top and bottom headings respectively, the lines could not be checked until Aug. 18. The final checking showed that the west line came 0.15 ft. north of the east line; the elevations checked to 0.13 ft., and the actual tunnel distance was 6 ft. longer than that calculated from the survey lines which had been run across the summit. The meeting of line and grade was considered very satisfactory. The 6-ft. variation in distance seems considerable, but it is explained that no special effort at great refinement was made in the surface measurement, as each time this was made in 12 to 15 ft. of snow.

The excavation was mainly in hard black shale rock, with some conglomerate, etc., the strata being inclined but slightly from the vertical, as shown by the geological section, Fig. 1. A considerable amount of water was struck in the conglomerate, due largely to small lakes (formed by the melting snow) on the east slope. There was water also in the loose material encountered near the west portal.

The tunnel was built by the railway company in accordance with its practice of doing practically all construction work with its own forces. J. I. Horrocks was Engineer and Superintendent under E. O. Reeder, Assistant Chief Engineer. All the work was under the direction of C. F. Loweth, Chief Engineer of the Chicago, Milwaukee & St, Paul Ry. The tunnel was completed and ready for traffic in January, 1915.

Design of Tunnel

The standard cross-section of the tunnel is 24 ft. high and 16 ft. wide, with a flat floor and a semi-circular roof arch, as shown in Fig. 2 The sides have a batter of 4 in. in 6 ft. above the top of the footing course. The tunnel is lined throughout with 12-in. of concrete, this being made necessary by the stratified condition of the rock (Fig. 1).

Embedded in the lining on one side are two 3-in. fiber conduits for telegraph wires and electric cables. On the same side of the tunnel are refuge chambers about 300 ft. apart, which serve also as inspection or splicing chambers for the conduits, as shown. The refuge chamber is about 2 ft. deep and 6 ft. wide, with a total height of 9 ft. 6 in., but at the top is placed the conduit box, so that the clear height is 6 ft. 6 in.

On account of the amount of water met with at various points, which must be provided for in the completed tunnel, concrete gutters have been constructed as shown in Fig. 2. The gutters are 12 in. wide and 10 in. deep, and at the refuge chambers they are covered with planks. One side is formed by the footing of the tunnel wall. The other side is a curb wall to retain the ballast.

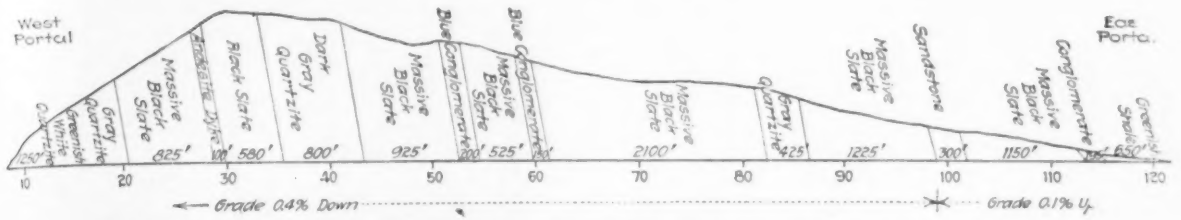


Fig. 1. Typical Geological Section Along the Snoqualmie Tunnel; C., M. & St. P. Ry.

To allow the water to flow from the tunnel into the gutters, 6x6-in. concrete baffles are placed diagonally across the tunnel floor at intervals varying from 150 to 300 ft. At each baffle the water passes through a grating in the curb wall and enters a 4-in. pipe which discharges into the gutter some distance further along. The object of this is to avoid having the gutter open directly to the tunnel floor. The baffles discharge the water on alternate sides, as shown.

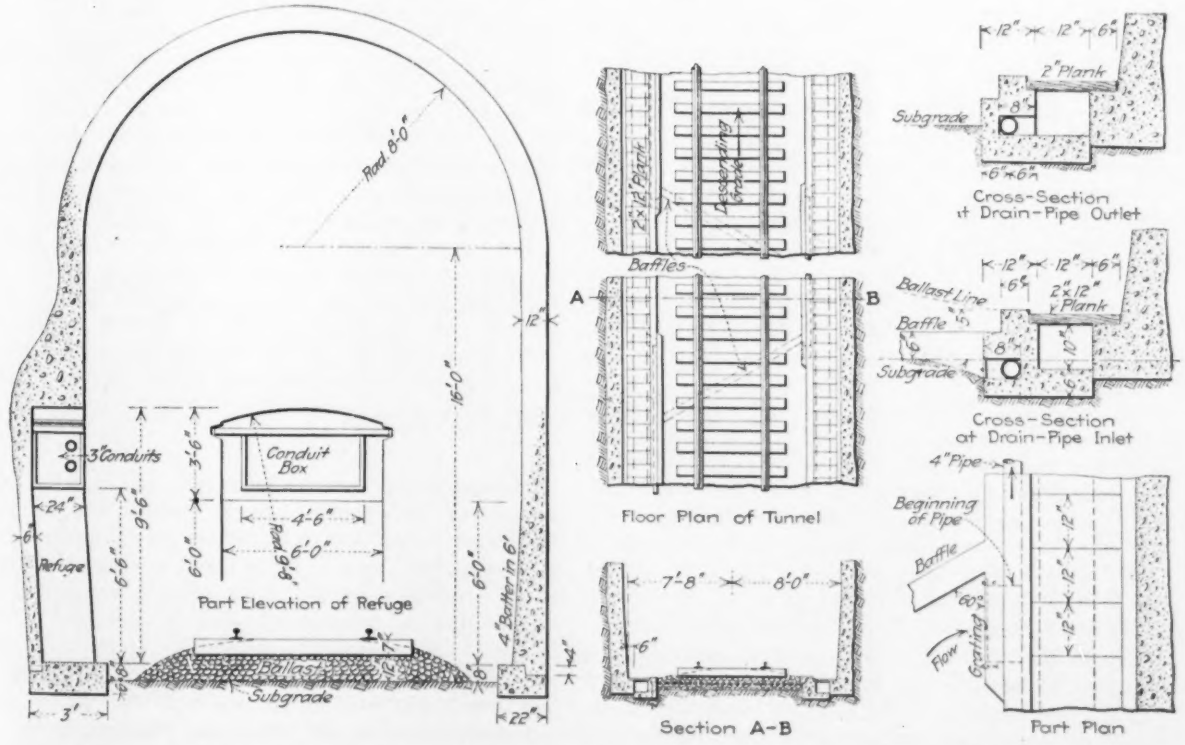


Fig. 2. Typical Cross-Section of Snoqualmie Tunnel, with Details of Refuge Chambers and Concrete Gutters

Methods of Driving the Tunnel

The construction of the Snoqualmie tunnel is of special interest on account of the use of the bottom-heading system (common in European practice) for the greater part of the work. This was adopted as giving greater speed and economy for the conditions under which this long tunnel had to be driven.

At the east end of the tunnel, however, there is a long and deep approach cut, and as this could not be completed until after the actual driving of the tunnel was in progress, it was decided to drive a top center heading at this end. This heading was widened to full arch section, and, to avoid placing temporary timbering, about 3000 ft. of the arch was concreted in advance of the removal of the bench.

The greater part of the tunnel was driven from the west end, using the bottom-heading system. A bottom drift 8 ft. high and 13 ft. wide was driven first along one side of the tunnel, and was then widened out on its other side to the full normal width of 18 ft. This full heading was timbered. The sets were spaced 5 ft. c. to c., and consisted of posts 12x12 in. with caps 12x14 in., upon which stringers and flooring were placed. The timbers were so arranged that the bench rock could be dropped directly to the 1½-yd. side-dump cars on the mucking tracks below.

At intervals of 150 ft., openings were driven upward to full tunnel section, and from these the bench was worked in both directions. The entire face was shot at one time. This gave both muckers and drillers continuous work in each bench stope and permitted the working of any number of stopes, depending on labor conditions.

A double-track narrow-gage line was laid as far as this bench work, a single track extending beyond to the face of the bottom heading. Horses operated the cars on this track, while at the bench the cars were made up into trains to be handled by gasoline locomotives. As the 1½-yd. cars were too high for hand shoveling, 1-yd. steel rocker dump cars were used for work at the face.

Four drills were used in the heading and were mounted upon a cross bar instead of upon tripods. For each round these drilled from 16 to 30 holes 9 ft. deep, depending upon the rock encountered. Usually there were 12 holes above the bar and four below, the latter acting as [illegible] in blasting. Steel plates laid on the floor facilitate the shoveling of the muck into the cars.

For ventilation, a 24-in. exhaust pipe was carried to the end of the completed bench and a 10-in. blower pipe was extended to the heading, this pipe within 100 ft. of the heading face being of canvas. As the distance from the portal increased, booster fans were installed at the blower line.

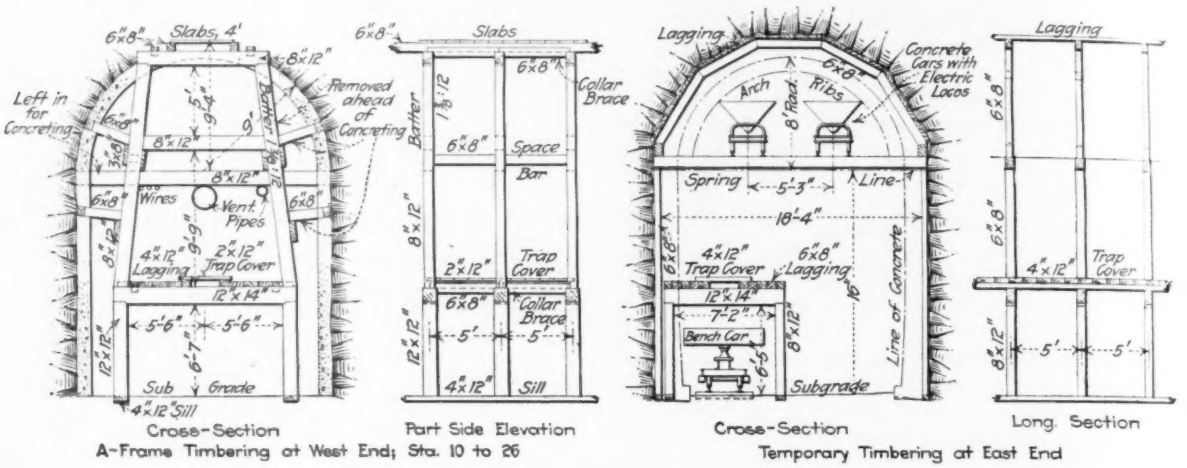


Fig. 3. Timbering of the Snoqualmie Tunnel; C., M. & St. P. Ry.

Each heading shift was composed of a foreman, 4 drill runners, 4 helpers, 10 muckers or shovelers, and a nipper. They worked 6-hr. shifts, with 12-hr. rest between shifts, except that the foreman and nipper worked 12 hr. These shifts were paid on a bonus system. The basis of this was 100-ft. advance for a 10-day period, and for each additional foot of advance each man on the shifts received one hour's extra pay. The average progress was 9.5 ft. of heading per day, with a maximum of 25 ft.

For work at the east end, under the top heading system, a center drift 9x6 ft. was driven first, with its floor at the springing line, and this was winged out to the full arch section. Shafts at intervals of 1000 ft. were sunk to the floor level, and stoping drifts were run from these at one side of the tunnel, from which the bench was taken out to the full section.

Concreting

The permanent concrete lining was put in while the tunnel was under construction, its purpose being largely to prevent fall of the roof. Where the excavation was in loose material at the west end, and was far in advance of the concreting, an A-frame timbering was put in to support the roof temporarily. This is shown at the left in Fig. 3. It was removed in advance of the arch concrete work, cross timbers being placed at the springing line to carry the track for the concrete cars. At the east end, some temporary timbering was required, as shown at the right in Fig. 3.

The concrete walls were built in lengths of 50 to 100

TABLE I. FORMS OF DAILY PROGRESS REPORTS ON THE EXCAVATION OF THE SNOQUALMIE TUNNEL; C., M. & ST. P. RY.

Daily Progress Report on Tunnel
West End (Bottom Heading System)

	Bottom Heading Lin.Ft. Driven						Top Bench Lin.Ft. Driven					
June 1914	Per Day	Total	Station	Per Day	Total	Station	Per Day	Total	Station	Per Day	Total	Station
	6	6822	74 + 80	.....	.....	.....	0	5696	63 + 54	.....	.....	.....
1	10	6832	74 + 90	.....	.....	.....	0	5696	63 + 54	.....	.....	.....
2	6	6838	74 + 96	.....	.....	.....	8	5704	63 + 62	.....	.....	.....
3												

Daily Progress Report on Tunnel
East End (Top-Heading System)

	Top Heading, Center Drift Lin.Ft. Driven			Top Heading, Enlarged Lin.Ft. Driven			Bench Lin.Ft. Driven			Remarks Cars of Tunnel Muck	
June 1914	Per Day	Total	Station	Per Day	Total	Station	Per Day	Total	Station	Bench	Heading
	16	3853	86 + 89	.....	.....	.....	4	1472	110 + 70		
1	16	3869	86 + 73	.....	.....	.....	4	1476	110 + 66	79	97
2	18	3887	86 + 55	.....	.....	.....	4	1480	110 + 62	95	126
3	16	3903	86 + 39	.....	.....	.....	4	1484	110 + 58	118	103

TABLE II. FORM FOR DAILY REPORT OF CONCRETING IN THE SNOQUALMIE TUNNEL; C., M. & ST. P. RY.

Daily Concrete Report, June, 1914
West End

	Right Footing			Left Footing			Right Sidewall			Left Sidewall			Arch					Actual Time of Plant in Operation
Date	Sta.	Lin. Ft.	Total Lin. Ft.	Sta.	Lin. Ft.	Total Lin. Ft.	Sta.	Lin. Ft.	Total Lin. Ft.	Sta.	Lin. Ft.	Total Lin. Ft.	Sta.	Lin. Ft.	Total Lin. Ft.	Cu. Yds.	Total Cu. Yds.	
	53 + 53	..	4689	53 + 81	..	4691	51 + 83	..	4493	51 + 93	..	4503	51 + 50	..	4437		23,747.0	
1	54 + 33	80	4769	54 + 78	97	4788	51 + 99	16	4509	.....	..	..	.....	..	..	29.5	23,776.5	11
2	55 + 00	67	4836	55 + 13	35	4823	52 + 47	48	4557	.....	..	..	.....	..	..	79.5	23,856.0	11

ft., and the roof arch in 12-ft. lengths. A concrete mixing plant was installed near each portal, and the concrete was transported in ½-yd. steel dump cars on narrow-gage tracks. These tracks were carried by cross timbers placed at the springing line and supported on posts until the side walls were concreted, as shown in Fig. 4. This arrangement enabled the concrete cars to be operated independently of the mucking cars, and it also enabled the concrete to be dumped directly into the forms for the sidewalls. That for the arch was shoveled into place. The cross timbers extended to the rock face and were left embedded in the concrete of the side walls, being sawed off level with the face of the walls after the completion of the work.

At the west end, the concrete cars were operated on an endless cable haulage system as shown in Fig. 4. At the east end (Fig. 3) they were operated by electric locomotives.

Progress Records and Reports

The greatest advance per month was 455 ft. in the west heading (March, 1913) and 433 ft. in the east heading (September, 1913). The maximum total advance for both headings was 785 ft. (May, 1914). The average daily heading advance was about 9.5 ft., with a maximum of 25 ft. for the west (bottom) heading and 24 ft. for the top center drift of the east heading. The progress diagram, Fig. 5, shows what a steadily uniform progress was made, the light straight lines indicating the average estimated progress. The heading work kept pretty closely to these lines. The bench work at the west end was slow, due to small force under labor conditions. On Dec. 31, 1914, the excavation of both benches had been completed, and the concrete lining was completed early in January, 1915.

The two forms of daily progress report of tunnel excavation are shown in Table I. The sheets are 8½ in. wide and 11 in. high. The report for the west end shows the bottom heading and top bench. That for the east end shows the center drift of the top-heading, the enlarged top heading and the bench; it has also a column for remarks, which in the example given is used to record the number of muck cars. The form for daily progress of concreting is shown in Table II, and is the same for work at both ends. This gives the progress on the different parts of the work, with the total advance, yardage and hours per day.

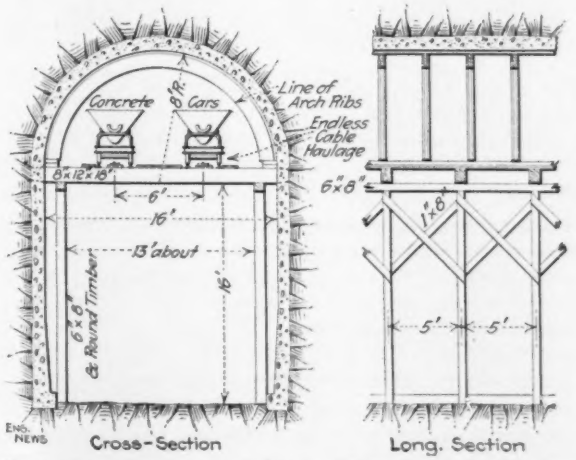


FIG. 4. TIMBERING TO CARRY NARROW-GAGE TRACKS FOR CONCRETING THE TUNNEL (ENDLESS-CABLE HAULAGE SYSTEM)

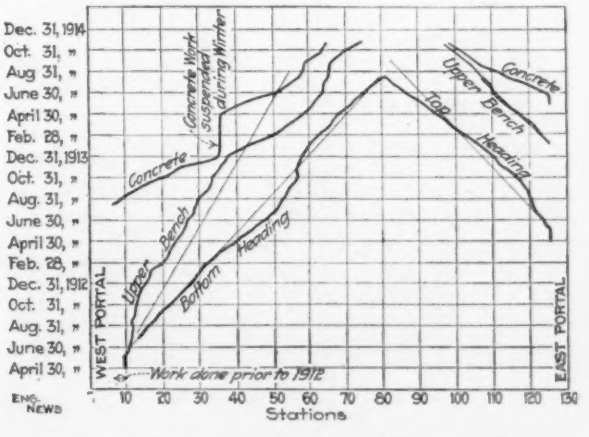


FIG. 5. PROGRESS DIAGRAM OF WORK ON THE SNOQUALMIE TUNNEL; C., M. & ST. P. RY.

Field and Office

Field Concrete Better Than Test-Sample Concrete

By R. E. Goodwin*

The results of tests of concrete made by pouring wet concrete into molds to form test specimens are now more or less generally known to engineers. These results are consistently lower than the figures used as a basis for safe stresses assumed in designing concrete structures and this fact is a source of concern to conservative designers. Field tests of 1:2:4 concrete cast in molds will not average over 1500 lb. per sq.in. after 28 days, as is shown by the results of a large number of tests made on subway construction work in New York City, and elsewhere.

As an offset to the startling nature of the above evidence, engineers frequently assert a belief that concrete possesses greater strength when it is placed in mass than when it is cast in molds of the size ordinarily used.

In order to obtain information on this subject the Public Service Commission, New York City, recently had several pieces of concrete cut from existing subway structures and tested. The portion of the structure from which the testpieces were to be cut was selected before the concrete had been placed in the forms, and while it was being poured samples from the same batch were cast in molds. In this way very interesting comparisons were possible between concrete cut from the structure and the same concrete cast in molds. In addition, samples of cement and aggregates were brought to the laboratory and were used for making laboratory specimens mixed in the same proportions as the field specimens. Some specimens were stored on the work in moist sand; others were stored in the laboratory moist-room and sprinkled daily.

At the end of two months pieces of concrete were cut from the structure at the place designated. These pieces were rough dressed and then polished smooth to exact dimensions on the rubbing table of a stone-cutting yard. They were tested at the age of 90 days. The results are shown in Table I. Each test was made on a different part of the work and the number of specimens averaged to obtain each result is indicated. Table II shows results of tests of a few miscellaneous pieces of concrete of various ages which were also cut from the structure. All specimens made on the work were machine-mixed. Those made in the laboratory were hand-mixed.

The average weights per cubic foot of the specimens in the tests in Table I were as follows:

Concrete cut from structure	147 lb.
Concrete from same batch cast in molds	150 lb.
Concrete made in laboratory from same materials	151 lb.

The head of concrete above the specimens cut from actual structures, while they were setting, varied from 3 to 15 ft., and the superiority of these specimens over those cast in molds may have been partially due to this circumstance. The specimens which were subjected to the greatest heads were not the strongest, however.

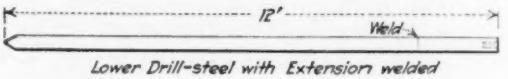
*In charge of tests of concrete and concrete aggregate, Public Service Commission, 154 Nassau St., New York City.

TABLE II. TESTS OF CONCRETE OF VARIOUS AGES CUT FROM ACTUAL STRUCTURES

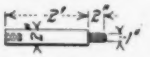
Lb. per Sq.In.	Proportions	Age	Description	Fine Aggregate	Coarse Aggregate	Consistency
1 = 4250	1 : 2 : 4	127 days	6-in. cube	Sand	Gravel	Wet
1 = 1870	1 : 2 : 4	15 mo.	8½x8½x17 in. rough dressed, not polished	Long Island washed bank sand	Long Island gravel	Very wet
3 av. 3340	1 : 2½ : 4½	30 mo.	6x6x12 in.	Cow Bay sand	Gravel	

Extension Drills in Tunneling

Drilling down 18 ft. in the bench in a tunnel heading with only 10 ft. headroom on the average has been accomplished at the new Kennerdell (Penn.) tunnel of the Pennsylvania R.R., by means of a drill-steel extension. The device is most simple, consisting merely of sections of steel with screw joints, as illustrated by the sketch.



Lower Drill-steel with Extension welded



McGuckin's Extension Drill-Steel, Used in Kennerdell Tunnel

The rock is a shaly sandstone in horizontal layers. It is easy to drill through and requires little timbering.

Until three months ago the two-bench method was employed at Kennerdell. Holes were put down 6 ft. and shot, and then the drills were again set up and the final

TABLE I. COMPARATIVE COMPRESSION TESTS OF CONCRETE CUT FROM ACTUAL STRUCTURES AND CONCRETE CAST IN MOLDS

(Size of specimens 6x6x12 in. 1:2:4 Concrete, 90 days old. All strengths in lb. per sq.in.)

Cut From 12-In. Wall	Same Batch Poured in Molds and Stored on the Work	Same Batch Poured in Molds and Stored in Moist-Room	Consistency	Same Materials Mixed in Laboratory and Stored on the Work	Same Materials Mixed in Laboratory and Stored in Moist-Room	Consistency	Fine Aggregate	Coarse Aggregate
4 av. 3095	4 av. 2880	4 av. 2870	Wet	4 av. 2135	4 av. 2080	Wet	Long Island beach sand*	Long Island beach gravel
4 av. 2410	.....	4 av. 1720	Very wet	4 av. 2225	4 av. 1930	Wet	Long Island washed bank sand	Long Island washed bank gravel
4 av. 2415	2 av. 2585	3 av. 2060	Wet	4 av. 1980	4 av. 1705	Wet	Long Island beach sand*	Long Island beach gravel
4 av. 2760	4 av. 2020	4 av. 1775	Very wet	4 av. 1900	4 av. 1910	Wet	Long Island beach sand*	Long Island beach gravel
16 av. 2670	10 av. 2480	15 av. 2110		16 av. 2060	16 av. 1910			

If concrete 90 days old be assumed to be 25% stronger than the same concrete 28 days old the corresponding totals for 28 days would be approximately as follows:

2150	2000	1700	1650	1550

*Coarse and well graded, not the very fine sand usually described as "sea-beach sand."

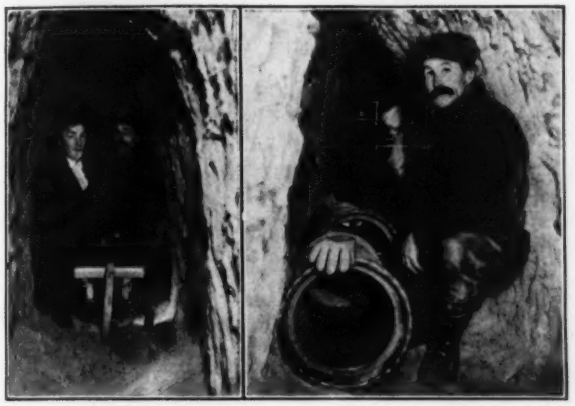
holes, 12 ft. deep, made. Four holes were drilled in the bench width.

By the new method one drilling operation was saved, with resulting economy in time and money. A hole, started with a 4-ft. steel, was put down to a depth of 12 ft. The last drill-steel had a 2-ft. end section with female screw welded on, and by this means a 2-ft. section was screwed on and the hole driven 2 ft. deeper. This process continued until the final depth was reached, when the sections were withdrawn and unscrewed.

The extensions were shipped to the job ready-made, and welded to the drill-steels at the local blacksmith shop. This new method was devised by Richard McGuckin, Superintendent for the tunnel contractor, John A. Kelley Co., Philadelphia, Penn. The work is done under the direction of A. C. Shand, Chief Engineer of the Pennsylvania R.R.; George Nauman, Assistant Engineer; George Patton, Resident Engineer. John A. Kelley, Jr., supervises the work for the contractor.

Earth Tunnel for Pipe Sewer at Virginia, Minn.

A 12-in. pipe sewer laid in a tunnel at a depth of over 30 ft. is an interesting piece of work at Virginia, Minn. The sewer serves one of the new additions to the city and has a length of 1727 ft., of which 1100 ft. are in tunnel and 627 ft. in open cut. The lines met with a variation in grade of only ⅛ in.



TUNNEL FOR 12-IN. PIPE SEWER AT VIRGINIA, MINN.

(The left-hand view shows the tunnel excavation with one of the special wheelbarrows. At the left side is City Engineer Johnson, and at the right is Street Commissioner Christopherson. The right-hand view shows the pipe being laid and backfilling placed)

The tunnel was started at the east end at a manhole where the depth was 22 ft. After finding the experiment successful, work was also started from the other end, where the depth of digging was 15 ft. The excavation was in glacial drift, with much hard clay and boulders.

After trying several distances between shafts, it was found that 75 ft. was very satisfactory. Only three men could work in a shift, as the cross-section of the tunnel was only 2x5 ft., varying somewhat where large boulders were met. One man with the usual picking tools and small scoops dug ahead into the drift. The second man shoveled the muck into a small wheelbarrow of special make and wheeled this to the shaft, dumping the dirt into buckets which were hoisted to the surface by a third man working a windlass. At first the advance was 8 or 9 ft. per shift, but later on with harder digging it was 4 to 5 ft. At the same time a night shift was put on. Regular miner's lamps were used. No timbering was necessary.

The laying of the pipe was kept 50 ft. behind the excavation. As the digging proceeded far enough into a drift the dirt was carried back to the pipe and there used as backfilling. In this way much of the hoisting was avoided. Vitrified clay pipe was used, laid as if in open cut. All of the tunnel and the shafts have been backfilled, except where manholes have been placed. These manholes are at street intersections and are 400 ft. apart. The deepest manhole is 37 ft., which is also the deepest point on the sewer. The grade is 0.4%.

The plans were prepared by E. F. Johnson, City Engineer. The work was done by day labor under the direction of C. Christopherson, Street Commissioner. The cost of the tunnel was $1.75 per lin.ft., which included all the labor used in tunneling, backfilling and laying the pipe, as well as digging the shafts. The pipe was furnished by a local contractor at 35c. delivered. The work was completed in January, 1915.

Thawing Ground for Trenching at Kalamazoo

By A. LENDERINK*

For the purpose of assisting the unemployed, the common council of Kalamazoo, Mich., decided to build now some of the sewers that were planned to be built during the summer of 1915.

The ground in the streets was frozen 18 to 24 in. deep. The engineering department decided to try steam as a means of removing part of the frost so that it would be

*City Engineer, Kalamazoo, Mich.

FIG. 1. VIEW OF ENCLOSED BOILER-TRUCK AND COVERED THAWING-LINE

easier for the men and also keep the cost of the excavation from becoming too great. The department has a 10-hp. upright boiler and engine mounted on a truck so that it can be easily moved about. A 1-in. steam line from the boiler was laid along one of the outer edges of the proposed trench for a distance of 100 to 150 ft. from the boiler and returned along the other edge. The part of the trench was then covered with some wooden sewer forms that the city used for large concrete sewer construction, and the forms covered with 6 to 8 in. of sand. The pipes were kept off the ground by a few bricks.

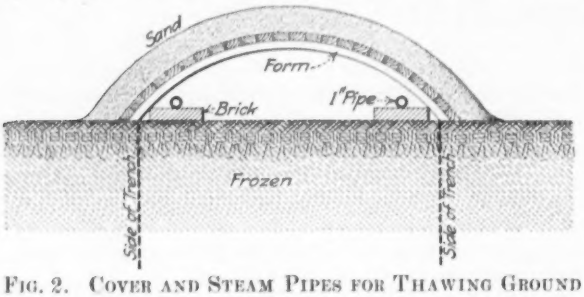


FIG. 2. COVER AND STEAM PIPES FOR THAWING GROUND

It was found that by keeping steam on the pipe for 24 hr. the frost in the part under cover was entirely removed. The moisture in the thawed ground allowed the men to shovel the top dirt out of the trench without using a pick to loosen it.

The pipes and forms were moved ahead each morning and the thawing started for the next day's work.

A portable shelter was built around the boiler (Fig. 1).

The cost of the thawing, for a trench 3 ft. wide, was 8 to 10c. per lin.ft., exclusive of interest and depreciation on the boiler.

Raising a Highway Bridge by End-Pin Slings

By R. C. HARDMAN*

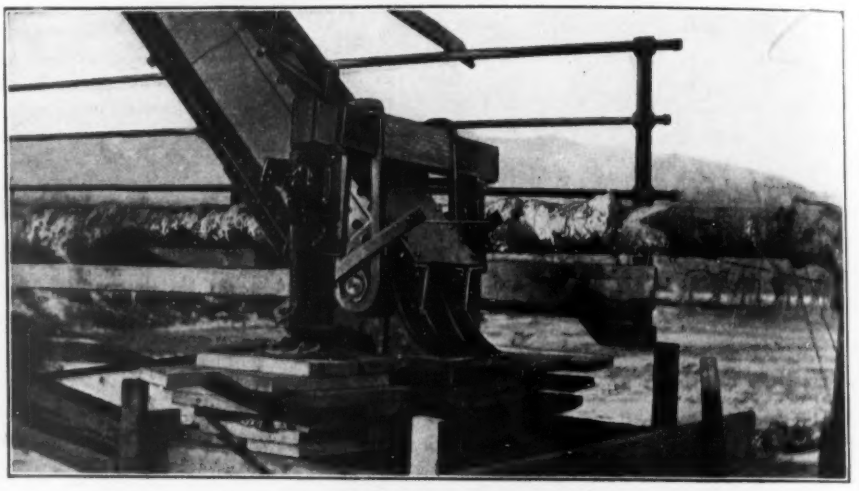
The writer has recently raised a highway bridge 5 ft. at one end by a method believed to be unique.

The bridge in question is a Pratt truss weighing about 85 tons, 105 ft. long pin to pin, spanning the Arkansas River at Cañon City, Colo. The raising was necessary to conform with the grade of a new reinforced-concrete viaduct with which it connects. The method of raising was by lifting the bridge from above instead of from below. This was accomplished by means of steel yokes placed around the nuts on the end pins, through the tops of which were placed I-beams to take the lift of geared screw-jacks.

The apparatus and method of application are shown clearly in the picture. The yokes were made of 1¼-in. square steel forged at one end to fit the hexagonal pin nuts and at the other to fit the flange of the I-beams; the weld was made over the I-beams. Between the nuts and yokes were placed strips of sheet lead to take up irregularities in the yokes so as to secure a uniform bearing on the nuts. The nuts were first turned to place one pair of sides in a horizontal position.

The I-beams used were 6 in. On the top flange, under the yokes, were placed ¾-in. steel plates to distribute the load and prevent any possible crippling of the flange at the edges. The sides of the I-beams were filled with wood to prevent any lateral movement of the yokes. The two yokes at each shoe were bolted together, directly above the nuts, to prevent any possible slipping off the nuts.

Four jacks were used. Three had 35 tons capacity each, the fourth 25 tons. These were placed under the



LIFTING THE END OF A 105-FT. BRIDGE

ends of the I-beams as close as possible to the yokes—in general about 6 in. away.

The raising was done by successive lifts of about 2 in. each: one truss was raised sufficiently to place a layer of 2-in. planks under its shoe, and then the other truss was raised to accommodate two layers of plank (i.e. 4 in.). In this process, continued alternately, one truss was always on a firm bearing while the other was supported by the jacks. When a height of 9 to 10 in. was reached by either truss, the supporting blocks were removed and their place taken by permanent blocking made of 4x8x16-in. concrete blocks laid up in cement mortar, and then the jacks were blocked up in the same way. At the end of each day's lift the space around the concrete blocking was filled in with 1:2:4 concrete to form a pedestal 4x5 ft.

The rate of lifting was variable. The first lift of about 13 in. was made in about three hours, the second lift of 32 in. was accomplished in five hours, and the last 15 in. in two hours. The force consisted of five men. The entire time consumed in raising the bridge the full height of 5 ft. was 2½ days, which included assembling materials and setting up the apparatus, lifting, placing temporary and permanent blocking, and concreting the pedestals. The work could have been done in much less time, but at the sacrifice of safety.

The bridge was erected in 1891. When as a prelimin-

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ary to the raising the expansion end, which was of the roller type, was uncovered, it was found that the slotted holes which provided for the expansion around the anchor bolts had been placed so that no expansion could take place. In other words the slot was on the wrong side of the anchor. All of the anchors were loose, which makes it seem probable that the expansion had been taken care of by the movement of the abutments and buckling. As the expansion end of the bridge was the one raised, the error was easily remedied.

Vacuum Sample-Tubes and Thermos-Bottle Container for Bacterial Samples

An ordinary thermos bottle for packing and shipping water samples long distances for biological analysis has been used with unqualified success for many years by George S. Binckley, Consulting Engineer, Los Angeles, Calif. He uses vacuum tubes of thin glass and after sealing them shut in the flame he puts them in cracked ice in a quart-size thermos bottle, for expressing to the laboratory. A long series of duplicate results, one by a laboratory near the source of the water, the other several hundred miles away (the samples being shipped to this distant laboratory by express), shows by the close agreement of results that the method is perfectly reliable.

The preparation and filling of the sample tubes are described by Mr. Binckley as follows:

A small standard test-tube is heated in the gas flame (having been previously cleaned with nitric acid and distilled water) and the upper portion drawn down to a diameter of about ⅛ in. The stem is then broken off, and the few drops of distilled water always allowed to remain in the tube before being drawn down are then boiled over the flame; when all the air has been expelled, and while the steam is still flowing out of the stem, the opening is quickly sealed in the flame, the steam condenses, and the tube is ready for use.

When the sample is to be taken, the outside of the stem is carefully cleaned, especially near the point, and sterilized by passing quickly through the flame of an alcohol lamp. The tube is then held, stem down, in the water, and, with the hands held down-stream from the tube, the stem is broken with a small pair of pliers, and the vacuum causes the water to flow into the tube. As soon as filled, the broken end of the stem is quickly and carefully sealed in the flame of the alcohol lamp, the tube is wrapped in a few layers of cotton cloth, and then placed in the cracked ice in the thermos bottle.

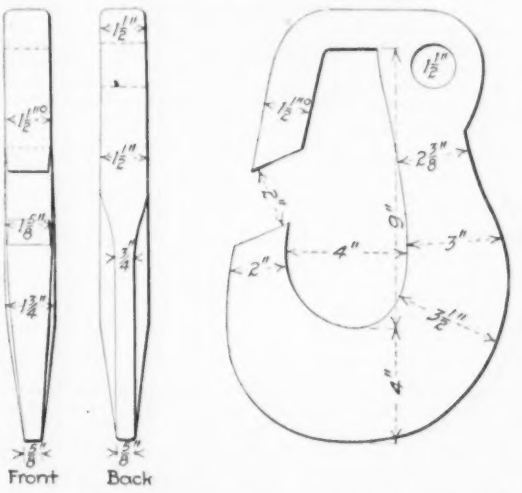
A more elaborate vacuum container, for use where the samples are bottled in thick-glass bottles, was described by R. S. Weston on p. 1265 of our issue of Dec. 24, 1914.

Safety Derrick-Hook for Handling Buckets

By N. R. Melvin*

The safety derrick-hook shown in the drawing is designed for use on derricks handling buckets with rigid bails over open timbered excavations. The object is to have a hook that will not become detached from the bucket till removed by hand.

It is a well known fact that the old-style hook will, nine times out of ten, unhook from the bail of a bucket when lowered to the ground if any "slack" is allowed to run out from the engine. It frequently happens in lowering a bucket into a timbered excavation that it will land, either through carelessness or misunderstanding of signals, on one of the cross-braces, become disengaged from the hook, and fall to the bottom of the excavation. At least one man was killed and another seriously injured on the present subway work during the past year from this cause. A hook of dimensions given in the drawing will safely sustain a load of 10 tons.



Melvin's Safety Hook for Carrying Buckets

*Superintendent for McMullen & Hoff Co., 131st St. and Lexington Ave., New York City.

NOTES

Collecting Data on Foundation Soil—Extensive collection of data on foundation soil has been begun by the committee on this subject of the American Society of Civil Engineers, headed by R. A. Cummings, Pittsburgh. A series of 59 questions has been sent out by the committee, classified in three groups, dealing with tests for bearing value, data on bearing value as deduced from existing structures, and local practice in bearing value of soil. The largest number of questions is in the second group, and it is specially stated that information given will be treated as confidential if this is requested.

Errors in Leveling Due to Slip of Extension Rod While Being Carried—In running about 200 mi. of level lines for topographic control in Wisconsin and Ohio during the field season of 1914, an unsuspected source of error was disclosed. Discrepancies amounting sometimes to 0.007 ft. appeared between the target reading by the rodman immediately after the sighting, and the second reading (without resetting) by the instrumentman after the rod had been carried about 300 ft. on the rodman's shoulder. The discrepancies occurred only when the target was on the upper section of the rod. Experiments proved that the swaying of the ends of the rod carried in this manner sometimes caused one section of the rod to slip on the other, in spite of firm clamping. The discrepancies disappeared when care was taken to carry the rod without noticeable vibration.—J. M. Perkins, Hudson, Mass.

Compensation of Rod-Reading Errors in a Long Line of Levels—In the same leveling just referred to two other kinds of errors were studied. Sometimes the line of sight ran over a summit, both the level and rod being on low ground. In careful leveling across such a summit when the weather conditions favor refraction, it was found that the line of sight should clear the summit by at least 2 ft. The work was fairly precise, closing within the limits of error prescribed by the formula $e = 0.05 \sqrt{\text{length of circuit in miles}}$. The work was done with a good 22-in. wye-level and a New York type of rod reading to 0.001 ft. While text-books state that some errors tend to compensate, the records of current experience are more satisfying to the mind. Here is such a record. Both the instrumentman and the rodman kept notes of the readings of the target rod, and the instrumentman made it a rule not to take notice of a difference between readings of 0.001 ft. in any one reading. In consequence of this many such differences

occurred in the notes. Nevertheless, the greatest difference in computed elevations between the two sets of notes was only 0.013 ft., the lines varying in length from 6 to 25 mi.—J. M. Perkins, Hudson, Mass.

Comparative Tests of Trap Rock and Slag as concrete aggregate have just been made for the National Slag Co., of New York City, by Prof. Harold Perrine at Columbia University. The Hudson River trap was separated into ¾-in., ½-in., ¼-in. and dust and was artificially graded to the natural gradation of the slag, which was used as furnished by the company. A 1 : 2 : 4 (by volume) mix and a standard sand and cement were used for all test cylinders. The results were as follows:

COMPRESSION TESTS ON 8x16-IN. CONCRETE CYLINDERS
(1 : 2 : 4 mix, 28 days old)

	Weight of Aggregate Lb. per Cu.Ft.	Weight of Concrete Lb. per Cu.Ft.	Compressive Strength Lb. per Sq.In.
Trap rock	100	154.5	1769
			2120
			2025
			1988
			1976 = Av.
Slag	80	140.6	2367
			2275
			2470
			2750
			2466 = Av.

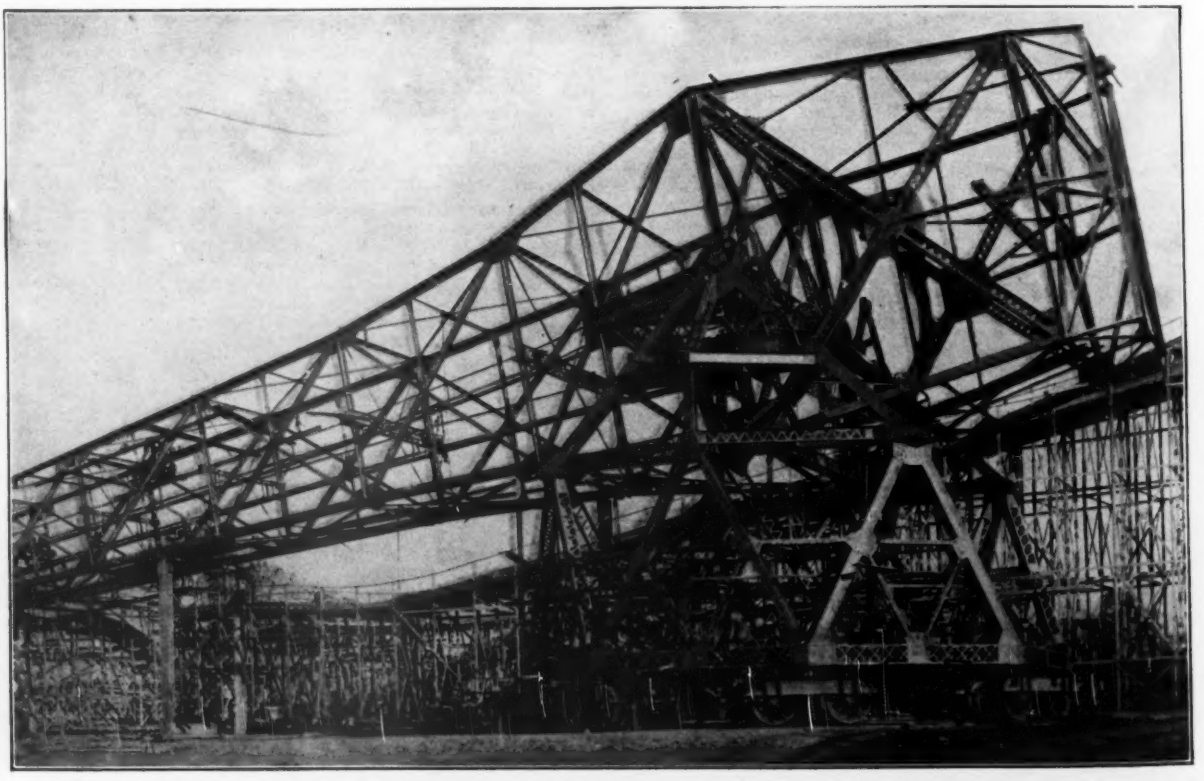
The Bascule Bridge Turned Into an Amusement Device—What amounts to a 250-ft. steel bascule bridge journaled near one end on trunnions mounted on a swingbridge turntable, and carrying at the other end a car for passengers, is one of the novel amusement devices installed in the "Zone" at the Panama-Pacific Exposition. The turntable tower is 48 ft. high to the trunnions and rolls by eight four-wheel trucks on a standard-gage circular track 61 ft. in diameter. The swinging arm or "bascule" is 242 ft. 10 in. long; the short arm is 38½ ft., the long arm 204 ft. 3¾ in.

Some details of the structure are as follows: The track is built of 90-lb. T-rail laid on stone ballast 2 ft. deep; radius-rods preserve its circular shape. The bascule is journaled on two 15-in. shafts 8 ft. 9¼ in. long, resting in phosphor-bronze bearings. The tail is counterbalanced with concrete. The width of the bascule is 35 ft. 9 in. at the trunnion and tapers to 8 ft. at the outer end. The car, 19x38 ft., double-deck, is connected by links and arms to the tower so that the car is kept in vertical position.

The bascule is raised and lowered by two 8-ft. a[illegible] propellers driven by two 3-hp. electric motors, located [illegible] ft. from the outer end of the arm, and by gearing at the [illegible] in trunnion driven by an 11-hp. motor. The tower is r[illegible]d on its track by four 15-hp. alternating-current [illegible]s mounted on four of the trucks. Water ballast tanks [illegible] alongside the car permit of keeping the structure [illegible] balanced for all loading, the concrete counterweight [illegible] adjusted for full load, i.e., 120 occupants or 18,000 lb.

The structure is owned and operated by the Pacific Aeroscope Co. J. B. Strauss, Chicago, designed it. The steel was fabricated by the Modern Structural Steel Co., Waukesha, Wis., and erected by the George H. Griffin Co., Seattle, Wash. The machinery was installed by the Butte Electrical Construction Co., San Francisco.

Industrial-Railway Equipment for Road Work—A typical equipment used in the construction of a 12½-mile waterbound macadam road 10 ft. wide, in Illinois, consisted of two 20-hp. locomotives, six miles of portable track and sixty 1½-yd. steel dump-cars. The rails and steel ties were made in 15-ft. sections, each weighing 225 lb. There were two flat-cars for hauling the track, but the frames of the dump-cars coupled together with 6-ft. poles answered better for this purpose. The track crew of four men could lay an average of 2000 ft. of track per day. In order to keep the track in good alignment one man was required to go over the track continually watching for and correcting low joints and loose connections. This care greatly increased the efficiency of the locomotives. By placing 10 to 12 loaded cars ahead of the locomotive and from 12 to 16 cars behind it, depending on the grade, one locomotive could handle long trains. Where the grade was 4% or over, the engine dropped the rear end of the train and pushed the forward cars to the top of the hill, going back for the other half of the train. Switching in the yard was handled by a mule. The equipment on one job was leased for six months, and in a little less than five months 35,473 cu.yd. of stone were handled with an average haul of 3.17 miles. The cost on the rental basis, which included all expenses incurred in the hauling as well as the freight on the plant both ways, was 14.8c. per ton-mile. This included also the necessary expense to put the equipment in first-class shape. It is estimated that team haul on this job would have cost at least 28 to 30c. per ton-mile.—Fred Tarrant, Div. Engr., Ill. Highway Dept.



INVERTED PENDULUM "AËROSCOPE" AT THE PANAMA-PACIFIC

Editorials

A Great International Exposition

The official opening this week in San Francisco of the fourth great International Exposition ever held in the United States is an event well worth the special attention of engineers. For one thing the official name of the exposition indicates that it celebrates the completion of the greatest engineering work in the world, the Panama Canal. Hardly less does it celebrate, however, an achievement quite as remarkable as the work done in joining the oceans at Panama. We refer to the wonderful restoration of the city of San Francisco after the destruction which swept over it in 1906. Never was there a more remarkable illustration of the indomitable courage inherited by the descendants of the western pioneers than the manner in which the people of San Francisco resolutely faced the task of clearing away the ruins and building their city anew.

This great work was indeed far from completed when San Francisco zealously embarked on the task of creating an international exposition that should worthily represent the United States and compare favorably with the previous great expositions at Chicago and St. Louis. There has been need of courage in the conduct of this enterprise, for the terrible catastrophe which has overspread the world for the past six months so absorbed men's minds here as well as in Europe that the public has had but little thought to give to San Francisco's attempt to bring all nations together in friendly competition, and it has been evident that the representation and attendance from European nations must fall far short of what had been hoped. There was nothing for the exposition authorities to do, however, but to go straight on with the program they had originally planned, and what they have accomplished is something of which every loyal American may well be proud.

As a proper recognition of this great national and international event, the present issue of ENGINEERING NEWS is made nearly double its usual size, and is made noteworthy by a series of special articles on the engineering works of the city of San Francisco, as well as the Pacific Coast, many of which will be the object of interested study by engineers who are fortunate enough to visit the exposition this season.

The holding of great international expositions may be said to have had its origin in the famous London "Crystal Palace" Exposition of 1851. Compared with the achievements of later years, that exposition was a small affair, but it was as large in proportion to the industries of that day as the great displays of Chicago in 1893 or at Paris in 1900 were to their times.

It would be difficult to overestimate the value as a means of public education in the arts and industries of the Centennial Exposition at Philadelphia in 1876. America at that period had no such close connection with Europe as exists today, and the foreign displays there were a revelation to most visitors. Since that time, the great development of technical journalism has largely displaced the exposition as a means of spreading knowledge concerning engineering and mechanical progress.

The great public service rendered by the Chicago exposition of 1893 was not in promoting the development of engineering science but in educating the public taste for the beautiful in architecture. A similar benefit will without doubt result from the splendid buildings which have been reared beside the Golden Gate to house the Panama-Pacific Exposition.

As a matter of interest, we present herewith a table compiled from the best sources of information available, comparing some of the noted international expositions held since the Crystal Palace Exposition of 1851. Some of the figures given in the table should be used only broadly, as the computation may not have been made on the same basis for different expositions. The figures of total cost, for example, in the recently held expositions include the entire expenditure by exhibitors as well as by the exposition organization, while in the earlier expositions it is probable that only the latter is included.

The probabilities are strong that a long time may elapse before another great international exposition is held. It will take time to efface the barriers between nations which the events of the past six months have created, and the world for years to come will need its wealth for necessities. Those who are able to visit San Francisco this year, therefore, will take advantage of an opportunity not likely soon to recur.

TABLE I. COMPARISON OF INTERNATIONAL EXHIBITIONS

Exhibition	Grounds and Buildings, Acres	Buildings, Acres	Expenses, $	Receipts, $	No. of Visitors	No. of Days Open
London, 1851	21	18½	1,500,000	2,530,000	6,039,195	141
Paris, 1855	34	29	1,700,000	1,280,000	5,162,330	200
London, 1862	....	25	2,500,000	2,050,000	6,211,103	171
Paris, 1867	120	37	4,000,000	5,230,000	10,200,000	217
Vienna, 1873	....	40	11,000,000	1,030,000	7,254,690	186
Philadelphia, 1876	285	50½* / 71½	8,500,000	3,800,000	9,610,900	159
Paris, 1878	152	60	11,000,000	4,635,000	16,159,719	194
Paris, 1889	238	54* / 75½	8,000,000	10,000,000	32,354,111	183
Chicago, 1893	666	105* / 150	30,000,000	28,239,000	27,539,521†	183
St. Louis, 1904	1200	128*	50,000,000	.....	19,694,855†	214
San Francisco, 1915	637	64½	50,000,000	.....	.....	...

* Area of main buildings.
† The paid admissions were 21,479,631 at Chicago and 12,804,616 at St. Louis.

Rate Regulation in California

The annual fixing of water rates by California municipal authorities, which has been so fruitful of litigation for years past, will end as soon as the legislature passes an act putting into effect an amendment to the state constitution which was adopted last November on a referendum vote. For several years the Railroad Commission of California has had jurisdiction over the rates and services of all public-utility companies outside of incorporated municipalities, and within such municipalities as surrendered their powers in this respect to the Commission. The amendment of 1914 unconditionally vests

the rate-making powers in the Commission (when provided for by the legislature), but leaves police, sanitary, and all other powers of control except over rates with the local authorities until surrendered to the Commission by local popular vote. This change from state to local regulation of utility rates is significant, for California has been one of the strongest, as it was also one of the first, "municipal home rule" states in the Union. It appears that a short trial of state regulation of rates outside the cities and incorporated towns and in such incorporated places as surrendered control to the Commission was sufficient to show the greater efficiency and economy of state as compared with local regulation, even in the larger cities.

Proposed Amendments to the Ohio Conservancy Law

Of the two major amendments to the Ohio Conservancy Law proposed in a bill now before the Ohio Legislature (Senate, No. 38), one seems bad and the other good. The bad amendment would prohibit the construction of detention reservoirs, a matter which should be left to the discretion of district authorities and their engineers. The good amendment provides that the directors of conservancy districts shall be elected by the people instead of appointed by the conservancy courts (composed of county judges). As we urged in our issue of Feb. 5, 1914, p. 312, the appointment of directors by the court, as well as some other features of the law, is not in accord with sound principles of representative government and administrative efficiency. This amendment is still not fully in accord with such principles, in that the directors of a district embracing only a part of a county would be elected by the county as a whole, but that defect could be easily remedied by the legislature.

Wire-Drag Surveys for the Alaskan Coast

We have previously had occasion to call attention to the efficacy of the long wire drag or sweep*, as developed by N. H. Heck, Assistant of the United States Coast and Geodetic Survey, in revealing dangerous obstructions to navigation, which could not be discovered in any other way save by a disastrous shipwreck.

Certain types of sea coast cannot be adequately surveyed without the extensive use of this very valuable hydrographic survey instrument. Much of the coast of Alaska is in this class, and in his recent annual report Secretary of Commerce Redfield strongly urged the appropriation of $200,000 to carry out a wire-drag survey of the more important Alaskan ship channels.

The appropriation has not yet been made, but a very remarkable demonstration of the necessity for such a complete survey has recently occurred. One Coast Survey party under Assistant John A. Daniels has been engaged in making wire-drag surveys in southeastern Alaska for the past two years. This party has just discovered a pyramid rock which rises 600 ft. from the bottom to within 17 ft. of the surface of the water. It is surrounded by 109 fathoms of water, and the chance that this "submerged Washington Monument" would have been discovered by sounding lines is nil.

The rock walls of the channels of this part of the Alaskan coast are nearly straight up and down, both above and below the water. Depths from 20 to 100 fathoms are within 100 yd. of shore. In these waters, which are the main thoroughfares of the popular inside passage, 21 dangerous rock pinnacles have been discovered by wire-drag surveys.

It is obvious what chances shipping is taking in these waters. It is equally obvious that the financial loss in the wreck of a single steamship would more than pay for a wire-drag survey of the entire coast. It is to be hoped that Congress will make the appropriation urged by Secretary Redfield.

New Points in the Edison Fire

The elaborate report on the Edison fire which the National Fire Protection Association has had prepared should be in the hands of every concrete engineer and everyone interested in fires and fire prevention. It furnishes excellent proof that the great plant was dangerously arranged and showed a disregard of all principles of subdivision and isolation of hazardous elements. The apparently spontaneous origin of the fire, in a can of motion-picture films, is held to emphasize the danger residing in nitrocellulose film—a conclusion having very extensive application.

The causes of injury to the concrete buildings are the most interesting item dealt with in the report. Longitudinal expansion of the floors is blamed for all the serious column failures. It is obvious that when different temperatures prevail in two superimposed stories, as when one story contains a hot fire and the other no fire, the floor exposed to the high temperature will expand, and the columns supporting it must bend; if the expansion is very great, the bending may be enough to break or shear off some of the columns. It is virtually demonstrated that this action caused practically all the column failures in the Edison buildings. Granting that this action did shear off many columns, however, we think it remains true that the injury done by spalling of columns is at least equally serious, and that it did not merely result in defacing the columns but produced extensive structural injury, and in a few cases failure.

Both these matters—the action of expansion in a long building and the damage by spalling of columns—call for most careful consideration in designing future concrete buildings. Whether the subdivision of large floor areas into self-contained fireproof units is sufficient to keep the expansion trouble within safe limits or whether expansion joints must be provided is a debatable question. On the second point, spalling, we fortunately find the solution in the Edison buildings themselves—the few round columns in the fire zone did not spall.

As to these and the many other subjects of study in the Edison buildings, it is important to note that the conclusions apply to *all* concrete buildings, and not merely to such as will contain films or wax or are to be used for phonograph manufacture. If a building is to be built fireproof, the principles of proper construction and proper fire-protection must be applied just as rigidly for favorable as for unfavorable occupancy. Whatever teachings come out of the Edison fire, they will have universal application.

*Described in detail in "Engineering News," Dec. 1, 1910, and Aug. 27, 1914.

Colorado River Control

The perennial problem of controlling the flow of the lower Colorado River and saving the fertile Imperial Valley, in Southern California, from ruin by flooding is again to the front. (See p. 285 of our issue of Feb. 11, 1915.) The proposed Congressional appropriation of $100,000 is conditioned on the raising of a like sum by the Imperial Valley Irrigation District, but the total of $200,000 is less than half the amount estimated by Gen. W. L. Marshall, Consulting Engineer to the Interior Department, to be necessary to avert danger from the high water of June, 1915. Moreover, even the $430,000 expenditure advised by General Marshall is only a fourth of what was recommended by President Taft in 1912 as needed for *temporary work*.

The breach which threatened in 1914, and was averted by emergency repairs, is likely to be enlarged by the June flood unless effective preventive measures are taken meanwhile. General Marshall says that "the river is now against the levee or near its toe for two miles, and threatens its destruction for five miles." If this levee fails, the flood water will sweep down through the Imperial Valley into the old Salton Sea, some 300 ft. below sea level.

To save the Imperial Valley, Congressional assistance is imperative, not only because money is necessary but because it requires the strong arm of the federal government to deal with the international situation. Heavy as is the financial burden, the international problems are a greater difficulty, because the river can be controlled only by doing work on Mexican soil. The situation was complicated enough before Mexico fell into its present state of anarchy. Since then, such protective work as has been done has been carried out under grave difficulties. Last year only Mexican laborers, mules, etc., could be used and on some materials taken into Mexico from the United States as high as 1500% duty was imposed!

The United States could well afford to pay Mexico a liberal sum to have the Mexican portion of the Colorado Delta transferred to the United States; but the difficulty of finding any authority in Mexico able to give an undisputed title to such territory would be more serious than controlling the river's floods.

Appointing a Lawyer to Build Highways

Dr. Richard T. Ely of the University of Wisconsin in a recently published masterly analysis of some of the causes why our governments make a failure in the work of carrying on business says:

> Our present system gives us a government by lawyers to an extent unknown in any other civilized land, and very largely a government of second- and third-rate lawyers.

An extreme illustration is reported from Missouri where Governor Major has just appointed a lawyer to fill a vacancy in the office of County Surveyor of Jackson County. In defending this appointment Gov. Major is quoted as saying:

> I wanted a man of executive ability, upon whose honesty I could implicitly rely, to administer the affairs of the office. He will have the overseeing of the expenditure of more than a million dollars in the next two years and I wanted a man familiar with road work in Jackson County who could administer the office efficiently and see that a dollar's worth of work is put on the roads for every dollar spent, and that every contractor lived up to the letter of his contract. have that man in Judge Southern.

The Engineers' Club of Kansas City has made a formal protest to the Governor against this appointment, not because Judge Southern is not a man of high character, but because the office requires engineering training and experience.

Governor Major lays great emphasis on honesty as the requisite which caused him to select a lawyer for an engineer's job; but no one—unless they wish to deliberately go out of their way to libel the engineering profession—will deny that there are plenty of capable engineers to be had whose honesty and fidelity to trust are beyond question. In fact it is very rare to find an engineer who is unfaithful to his trust. Can as much be said of the legal profession?

There is another conspicuous instance in the East. Governor Whitman of New York has recently announced the appointment of Edwin Duffy of Cortland as head of the New York Highway department, in place of John N. Carlisle, the announced reason being that Duffy was a college classmate of Mr. Whitman's and the Governor wanted someone at the head of the Highway department on whom he could rely to carry out his policies.

We have nothing to do in this journal with personalities or with politics. The reason why both Governor Whitman's and Governor Major's appointments deserve condemnation is because they entirely ignore the fact that the building and maintenance of highways is a matter of engineering and not a matter of legal lore. There is as much sense in these appointments as there would be in appointing an engineer as a district attorney or a lawyer as attending physician to a hospital.

It takes something besides honesty to build and maintain roads and do it economically. Of course these lawyers acting as county surveyors and highway administrators cannot really do the work they are appointed to do and are paid for. What has to happen is that they hire—at the public expense—some engineers to do the work for them. What private business could survive if carried on by such methods? Engineers may rightly protest against such denial to the engineering profession of the power and responsibility that rightfully belong to it.

The Ocean Shipping Business

Most American civil engineers are more or less familiar with the economics of land transportation, especially in connection with railway construction and operation. Comparatively few, however, are familiar with the ocean-shipping business, which is just now brought to public attention by the sharp controversy in Congress over the proposal that the government itself shall go into the shipping business. It is unfortunate that this controversy has become a political issue for it is a question which can only be intelligently discussed and settled with a clear understanding of the commercial and economic and engineering questions involved.

It has been made clear that many of those who favor the government shipping bill do so because of their belief that the government ought itself to carry on many undertakings which in the United States have been left to private enterprise, such as railways, coal mines, telegraph and telephone systems, and public utilities in cities. It is

perhaps worth while suggesting to those who hold such ideas that the ocean freight business is one which is so difficult to make economical and efficient when conducted on a large scale that the government would be extremely likely to make a failure of it if it undertook it; and that such a failure would be a powerful argument against the extension of government activity to other fields where a much stronger case can be made out in favor of government operation.

In saying that the ocean freight business is one difficult to carry on economically on a large scale, we are referring not to the so called line traffic, by which passengers and high-grade freight are carried on the principal traffic routes across the seas, but to the tramp ships, which carry the bulk of the raw materials moved in the world's carrying trade, such as grain, lumber, coal, ores and fertilizers. It is the tramp shipping business in which the fiercest competition rules, a competition which has reduced the cost of bulk freights on ocean voyages to an amazingly low figure. Notwithstanding this competition, the tramp shipping business yields far larger profits to the firms that thoroughly understand it than are earned by the great steamship lines. A suggestion as to the contrast between the situation of ocean line traffic and ocean tramp traffic is furnished by the fact that at this very time, when some tramp steamers are making profits on a single voyage equal to the entire cost of the vessel, the so called shipping trust, although relieved of the competition of its two great German rivals, is about to be reorganized because it is unable to pay the interest on its bonds; and during the ten years of its history it has never paid a dividend on its stock.

The rapid changes in the shipping business are illustrated by the statement of one of the leading ship owners of Great Britain in a presidential address at a recent meeting of an engineering organization devoted to ocean-shipping matters. He remarked that on the much discussed question as to the relative durability of iron and steel ships, he deemed it well settled that the steel ships had a shorter life, but that this fact made little difference since an ocean freighter became obsolete long before she became unseaworthy through corrosion of her hull plates.

To any of our readers who desire to familiarize themselves with the ocean-shipping business, we recommend a book entitled "The Ocean Carrier," by Dr. J. Russell Smith, of the University of Pennsylvania, which should be obtainable at most public libraries. At this time when so many engineers have to deal with questions of water terminals, export traffic, etc., knowledge of the actual conditions under which ocean transportation is carried on is likely to be useful to an engineer.

It is well to point out, however, that the conditions now existing in ocean transportation, which are wholly unprecedented within the memory of anyone now living, might be made to justify the government's undertaking the carriage of ocean freight.

It is of course true that the conditions which now exist in ocean shipping are wholly without precedent and that these conditions may be made to justify the government in operating merchant vessels for commercial freight when it could not be justified under ordinary conditions. The exigencies of the war have already caused the United States government, as well as the governments of Europe, to undertake work always left hitherto to private enterprise; an example is the federal marine-insurance bureau.

The most essential thing, however, for restoring normal conditions in the ocean-carrying trade is the construction of new vessels to take the place of the large number which have been destroyed during the past six months. It will probably be years before the shipyards of the world will be able to turn out enough new vessels to meet the needs of international commerce. The ship-building industry in the United States has been for a long time one of little profit, and the present situation may eventually enable this country to develop both a successful merchant marine and a substantial ship-building industry.

Letters to the Editor

Experimental Study of Wind Pressure Needed

Sir: Mr. Fleming's articles on wind pressure appear to recommend a smaller amount for this force in the design of buildings and other structures. Information is admittedly insufficient; yet on p. 211 of your issue of Feb. 4, 1915, a mere statement is made that wind pressure on an exposed surface decreases per square foot as the area becomes larger and that for this reason 20 lb. per sq.ft. for wind is an ample assumption. The results (p. 163) of experiments on Forth Bridge do not seem pertinent. Pressure is maximum on small spots. Also these results evidently include pressure and suction. The latter, at the center of a large area, might be zero or, since there is not a vacuum but deflected motion at that point, there might be pressure instead. The tests should be on small spots of large and small areas, pressure and suction measured independently. An average could then be taken. Theory would, however, lead to the conclusion that this unit force rather increases with area obstructed; Trautwine's pocket-book intimates similar views to mine.

The direct measurement of wind pressure and suction under various conditions of sizes and wind velocities would be a matter of small expense when compared with the importance of this subject. Are there funds available for useful scientific investigations? If some prizes were offered as a reward for the best answers based on certified evidence by means of tests, there would probably be many parties who by availing themselves of existing facilities and opportunities might soon furnish valuable results for public use.

CHARLES R. STEINER.

Long Island City, N. Y., Feb. 6, 1915.

Wind Stresses and Factors of Safety

Sir: Referring to the articles on wind stresses by R. Fleming, now running in your columns, and particularly to the issue of Feb. 4, it is to be regretted that the author did not add to the value of his service to the profession by seizing the opportunity to advocate a more logical plan of assumptions, by stating the reasonable loads, the reasonable ultimate unit-stresses, and proper factors of safety to be used in conjunction therewith.

While working stresses may be desirable in specifications, building codes, etc., the writer has always been of the opinion that an engineer needs to know the ultimate strengths, and to apply thereto factors of safety suitable for the installation in question.

Steel construction may be divided into three general classes: (1) bridges and city buildings, (2) miscellaneous light building construction, and (3) transmission-line supports, windmills, etc.

The writer's suggestion above applies particularly to the two latter classes, and the extension of Mr. Fleming's work to cover the third class would emphasize the need for the writer's suggested procedure.

The writer wishes to endorse heartily any effort to establish reasonable and actual loading assumptions, rather than a blanket requirement to cover all possible contingencies and ignorance. The logical extension of this method is of course to use ultimate breaking strengths and definite factors of safety, or, if working stresses are used, to state the factor of safety provided thereby.

In conclusion, the writer suggests the urgent need for a generally accepted logical and accurate curve of breaking strengths for light columns, such as single and double angles or similar members, and would suggest for discussion the following formula:

$$\frac{40{,}000}{1 + \frac{1}{16{,}000}\left(\frac{l}{r}\right)^2}$$

R. D. Coombs,
Consulting Engineer.

30 Church St., New York City, Feb. 6, 1915.

[Undoubtedly line towers and similar structures frequently must be designed on a basis of ultimate strength. This requirement is paralleled in few other kinds of structure; perhaps the nearest analogue is the calculation for emergency loading which is sometimes made for important bridges. However, a return to the *factor of safety,* that deceptive term which engineering has largely outlived, is highly undesirable. Would not the same purpose be fulfilled by a calculation for emergency conditions, with emergency stresses? For instance, if the extreme emergency condition is the anchor-tower condition, i.e., one span totally down and maximum ice and wind load, say ½-in. ice and 60-mile wind, then a stress calculation should show stresses somewhat below the normal failure-point. Just what stresses may be allowed in this calculation depends on conditions; for example, in a design of such kind that a tension member passing its yield-point might throw extra stress on another member, the extreme tension should not pass 35,000, while otherwise an extreme tension of possibly 45,000 might be accepted. In the matter of light columns, however, the base stress of 40,000 suggested by Mr. Coombs is higher than test averages warrant. A base stress of 30,000 to 35,000 for columns would be better. In view of the fact that no tower, so far as we know, ever failed in a tensile part, it would seem safest to add to the struts and economize in the ties.—Editor.]

What Is Gravel?

Sir—I note with interest the question, "What Is Gravel?" in Engineering News, Jan. 28, p. 180, and I agree with the writer that the question ought to be answered.

We have in nature, sand, pebbles and boulders. These are pieces of material of various kinds in their natural form with rounded edges and corners. It is generally understood that small pieces are sand, medium pieces are pebbles and large ones are boulders; but we also have the word gravel.

This word certainly is not synonymous with pebbles, because gravel is a mixture of sand and pebbles. Is it not, therefore, inconsistent in talking of concrete aggregates, to use the terms sand and gravel, and would it not be much more specific and definite to say sand and pebbles? It might be well to arrive at a decision as to what range of size is meant by the three words sand, pebbles and boulders.

We have another class of aggregates the pieces of which are not in their natural shapes but whose sizes are determined by crushers and screens. This class, of course, includes all crushed material, and, in speaking of such material, it is necessary to specify it by size.

B. F. A.

Chicago, Ill., Feb. 1, 1915.

NOTES AND QUERIES

Both the old concrete chimney and the new brick chimney shown in the article entitled "Tearing Down a 250-ft. Reinforced-Concrete Chimney," in our issue of Jan. 14, 1915, p. 78, were built by the Alphons Custodis Chimney Construction Co., of New York City.

The Municipal Asphalt Plant of New York City, referred to in a note on p. 237 of "Engineering News," of Feb. 4, manufactured paving mixtures for 129,877 sq.yd. of pavement and not 12,877 sq.yd., as a typographical error made the note read.

Natural-Gas Service Regulations have been adopted by the Public Utilities Commission of Kansas, effective Jan. 26, 1915. These fix the minimum heating value at 800 B.t.u. per cu.ft. with a semiweekly determination. Pipe line or producing utilities may make a single calorific determination applying to all the connected distributing utilities. Chemical analysis must be furnished on request. Pressure shall be not less than 2 oz. or more than 8, and the daily variation at a consumer's meter must not exceed 100%. Continuous pressure surveys must be made. All services shall be metered and distributing utilities must have meter-testing facilities. No meter shall be in service with an error greater than 1% at normal capacity, and no meter shall be in service more than five years without test and adjustment. Customers may have their meters tested on demand once a year. The commission will make meter tests at a fee of $2 up. If the meter is more than 2% fast the utility must pay the fee; a meter found more than 2% fast requires a refund to the customer for up to six months back. There must be records of meter tests, interruptions of service, complaints and accidents; records must be preserved for three years. Bill forms must show meter readings and all factors entering into computation of the amount. The service may not be discontinued without 48-hr. written notice. Distributing companies must send each patron each year an approved pamphlet giving full information on the economical adjustment and use of gas-burning equipment.

Meeting of the Connecticut Society of Civil Engineers

The thirty-first annual meeting of this society was held at New Haven on Feb. 9 and 10, with nearly one hundred members of the society in attendance. George K. Crandall of New London, the president of the society, in his annual address said that notwithstanding the general depression in business the large amount of municipal work in progress in Connecticut had kept most of the members of the society employed during the year and gave fair prospects of business for the coming season. Tellers who canvassed the letter ballot for the election of officers announced the following ticket: P. C. Elwell, New Haven, President; Clarence Blakeslee, New Haven, First Vice-President; Henry R. Buck, Second Vice-President; K. Frederick Jackson, New Haven, Secretary and Treasurer. Henry J. Kellogg, of New Haven, and Edward W. Bush, of Lyme, were elected members of the Board of Direction. The society, after some discussion, voted to adopt a code of ethics identical with that adopted by the American Society of Civil Engineers at its annual convention in Baltimore a year ago.

Among the papers read at the first day's session was one on the railroad development of Alaska, by C. M. Ingersoll, consulting engineer of New York City, who was a member of the Alaska Railroad Commission, which made preliminary explorations for railway lines in Alaska two years ago prior to the appointment of the present commission. Mr. Ingersoll was most sanguine as to the future prospects of agricultural and mineral developments in Alaska when transportation facilities are supplied.

R. E. Horton, of Albany, N. Y., gave an illustrated lecture on the development of underground water-supplies. In connection with this lecture there was exhibited by Mr. Jenks, of Pawtucket, R. I., the Mansfield water finder, an electrical instrument manufactured in England and claimed to indicate by the deflection of a compass needle the presence of underground veins of water. It was stated that this instrument has been used for several months as a guide in locating deep wells and with satisfactory results.

Among the important papers presented at the sessions on Wednesday was a description of a new ocean steamship terminal at New London, for which the State of Connecticut appropriated $1,000,000. The work was described by Waldo E. Clarke, of New London, resident engineer. A pier 1000 ft. long is under construction at this point and it is expected that the federal government will eventually deepen the water in the channel leading up to the pier from its present depth of about 28 ft. to 35 ft. Experience in the valuation of company-owned waterworks in Connecticut prior to their acquirement by the city was reviewed in a paper by Chas. E. Chandler, of Norwich. Herbert C. Elton, of New Haven, read a paper on the "Design of Structures to Support Overhead Wires for Railway Electrification." It is recognized that the high first cost and heavy maintenance cost of the overhead structure used on the electrified New York, New Haven & Hartford line is a heavy handicap to the extension of electrification. Efforts are being made to devise a lighter and cheaper overhead system both here and in Germany. Such structures, designed by the firm of Gibbs & Hill for the Norfolk & Western and Pennsylvania Railroads, were described by Mr. Elton.

Convention of the American Concrete Institute

The 11th annual convention of the American Concrete Institute, held at Chicago Feb. 9-12, 1915, comprised 11 sessions at which were presented 35 papers and addresses and six committee reports. The program was grouped under subjects, a day each being devoted to roads and bridges, to tests and design, to art and architecture and to plant management and cost. Nearly 400 members were registered, though probably on account of the concentration of the sessions, rarely more than 100 were present at any one meeting. The subject matter and manner of presentation of all of the papers were admirable and well worth the attention of all interested in concrete work. Inasmuch as the Institute is about to initiate the practice of printing in a monthly journal all of the papers and discussions presented at the annual convention, only the more important and timely papers will be reviewed here.

Concrete Design

One evening session, which did not adjourn until past midnight, was given over to the discussion of two papers on design, by Edward Godfrey, of Pittsburgh, and C. A. P. Turner, of Minneapolis. Mr. Godfrey's paper was a resumé of his now well-known indictment against current practice in concrete design, more especially as laid down in the report of the Joint Committee on Concrete and Reinforced Concrete. The criticisms reduce themselves to a claim that the report allows the use of a plain concrete column for lengths up to 12 times the diameter, that the so called rodded column is a dangerous element in design, that stirrups in beams are unnecessary and that the recent Chicago flat-slab ruling is unjustly favorable to that form of construction. Mr. Godfrey, who was present, was subjected to the heckling of a number of members, but his criticisms were answered soberly and reasonably by two members of the Joint Committee, Prof. A. N. Talbot, of the University of Illinois, and Sanford E. Thompson, of Boston, and by a representative of the Chicago building department.

Prof. Talbot acknowledged that the Joint Committee report was not perfect and that it could be bettered by a number of verbal changes which, among other things, would remove the remote possibility of its endorsement of a plain concrete column, but he stated that it was never intended as a treatise on concrete construction and was supposed to be used only by those acquainted with the elements of structural engineering. He stoutly defended the longitudinally reinforced column of proper design, and showed by tests that it does act as intended, that is, with a proper distribution of stress to both concrete and steel. He also showed tests demonstrating the efficacy of stirrups, although he admitted that the value of such stirrups would be lost if the horizontal steel was not tied into the supports of the beam.

The paper by C. A. P. Turner was familiar to those who have followed Mr. Turner's writings and would probably have provoked some discussion had Mr. Turner remained after its reading. Some urgent business, however, called him from the floor while several very pointed queries were pursuing him through the doors.

Structures

One of the most important papers was the report of the special committee on the Edison fire. The essentials of

that report will appear in an early issue of ENGINEERING NEWS. The main novel finding of the Committee is that the wall-column failures by shear were due to longitudinal expansion of the building, following vertical cracking due to the unequal expansion of the square column section. Other structural papers were on "Standard Designs for Concrete Highway Bridges and Culverts," by G. B. McCullough, of the Iowa State Highway Commission, a review of that commission's practice and an account of numerous failures due to bad design; "Test of a Reinforced-Concrete Slab Bridge," by E. B. McCormick, of the U. S. Office of Public Roads, a description of the first of a number of full-size tests to determine the distribution of loads on a bridge floor slab; and "Design and Construction of the Massachusetts Institute of Technology Buildings," by Sanford E. Thompson, Consulting Engineer, describing the preliminaries to design and the earlier construction of the large group of buildings now under way on the north bank of the Charles River in Cambridge.

P. M. Bruner, St. Louis, Mo., told of his patented method of securing dustless concrete floors by the placing of a cover of burlap weighted with cement and sand on the just completed floor surface, the principle being that the cover absorbs the excess water in the concrete, thus allowing it to set without the customary flushing to the top of the fine particles. The results have been eminently satisfactory. In the paper noted in the previous paragraph, Mr. Thompson stated that in the Institute buildings a dustless floor had been attained by the exclusion of all fine matter from the aggregate, thus precluding the possibility of such fine matter flushing to the surface. Further discussion of the subject developed an advocacy of boiled linseed oil as a dust preventive after construction.

Two papers were devoted to the new egg-shaped concrete sewer pipe, which has recently been successfully tested and later adopted for work in the city of Philadelphia.

A paper entitled "The Strength of Concrete Forms," by Harrison S. Taft, of Seattle, Wash., contained a most elaborate analysis of the design of such forms and a number of valuable tables to be used in form design.

Concrete Roads

Percy H. Wilson, of the Association of American Portland Cement Manufacturers, explained the work that association was doing in coöperating with concrete road builders. A large force of engineers and inspectors now covers the entire country and is ready to aid any engineer or contractor who has the construction of a concrete road under way. In addition to this educational work, the association, through its field force, is accumulating complete data on materials, construction and wear of every concrete road in the country, all of which information is available for study. Mr. Wilson stated that in 1914 about 15,000,000 sq.yd. of concrete paving and roadways had been laid in the United States, which is more than in all previous years combined. The experience of the past few years has developed the following facts in regard to concrete roads: more knowledge of aggregate is desirable and a suitable field test should be devised; metal protection plates at joints are not necessary; the concrete at the joints should be denser than elsewhere; more canvas covering during curing is necessary; aggregate should not be too hot lest the concrete set before placing; thicker roads are desirable; roads over 12 ft. in width should be reinforced.

The question of reinforcing roads was also under discussion, but practice in this regard seems very erratic and the theory of reinforcement highly debatable, so little of value was developed.

Figures on cost were given by Mr. Wilson and by H. J. Kuelling, County Highway Commissioner, Milwaukee, Wis.

A brief description was given in a paper by Wm. H. Cornell, of Philadelphia, of a new test concrete road recently laid in that city, wherein one of the accepted types of construction and material have been used. Service records and measurement tests are to be made public when available.

Committee Reports

The Committee on Concrete and Reinforced Concrete presented the final report on the tests of concrete columns poured from a building under construction in New York City. These columns, of full size, were of different types of design, and their test affords the latest and most nearly complete record of comparative performance. A summary of the tests will appear in an early issue.

The Committees on Treatment of Concrete Surfaces, on Roads and Pavements, and on Building Blocks and Cement Products, presented some slightly revised specifications and recommended practice, all of which were accepted and sent to letter ballot. The Committee on Nomenclature presented a tentative list of definitions, which are to appear in the *Journal* of the Institute and are then to be subjected to criticism by the members. The Committee on Highway Bridges and Culverts re-presented its last year's suggestions for specifications on highway bridges and culverts. The Committee on Methods of Tests and Standard Specifications for Concrete Materials submitted some of the results of comparative tests on aggregates made by different laboratories throughout the country.

Business Session

Owing to recent gifts of over $15,000 to the Institute, it now finds itself in excellent financial condition. A permanent secretary, whose activities will probably be directed toward publicity and building up the society, has been secured, and by the monthly journal and other projected services it is hoped to give the Institute a new impetus which will guarantee its rapid growth. The new president elected is Leonard C. Wason, of the Aberthaw Construction Co., of Boston, who succeeds Richard L. Humphrey, of Philadelphia, now retiring after 10 years of arduous service.

At the annual banquet, Mr. Humphrey and Mr. E. E. Krauss, the retiring secretary, were each presented with a handsome clock by the members attendant on the convention.

The offices of the Institute are in the Harrison Bldg., Philadelphia, Penn. Information regarding the papers referred to above may be obtained by communication with the Secretary, C. L. Fish, at that office.

State Highway Departments are now organized in all the States of the Union but seven; and 30 states now make direct appropriations for highway construction or maintenance, according to the American Highway Association.

TWO VIEWS OF FUSED CONCRETE IN BASEMENT OF WAX HOUSE, EDISON PHONOGRAPH WORKS
(Taken after fire of Dec. 9, 1914)

Concrete Was Melted in Edison Fire

Temperatures equal to the melting-point of concrete were reached in the great fire in the Edison Phonograph Works, West Orange, N. J., on Dec. 9, 1914, according to a joint report of the National Board of Fire Underwriters and the National Fire Protection Association. In this report, which covers all phases of the fire in detail, they say on the subject of temperatures:

The heat attained in this fire was exceptionally high and continued from 1 to 3 hr., owing to the quantity of inflammable materials and lack of water. Evidence of temperatures ranging from 2000° to 2500° F., and probably higher, was found in many places.

There were evidences of fused concrete on parts of columns, beams and floor slabs in basement of Wax House, No. 12. Several beams and floor slabs appeared to have wasted away as a result of this fusion. Slag has flowed down the side of the columns and hangs in stalactites from the bottom of the beams and floor slabs [see the two photographs reproduced herewith]. This would indicate a temperature of 2500° F. or more at this location. Reinforcing bars were also found melted where exposed by the fusing of the concrete in the beams and floor slabs.

There was also a limited quantity of slag and other evidence of fused concrete in the west end of the third story of No. 24, near the failed columns where heat from the burning wax was most intense. Similar evidence was found in the vicinity of the general collapse in No. 11.

A careful investigation of this slagged concrete, and the fusibility of concrete in general, is being made by the Bureau of Standards of the U. S. Department of Commerce. The results thus far obtained indicate that the formation of the concrete slag was due in part at least to intense heat. The investigation is not yet completed. It is, of course, possible that highly heated chemicals may have contributed to the excessive destruction found in No. 12. However, the fact remains that well defined samples of fused concrete were found in two other buildings, and it is hardly probable that the same chemical agencies would have induced the fusing in those cases.

Large pieces of steel and cast iron melted in a number of places, notably in Nos. 7, 11, 12, 15, 18 and 24. Melted copper and brass were commonly found, and glass, of course, melted freely almost everywhere.

Steel pipe and other steel parts where found melted indicated exceptionally high temperatures, as fluxing or slagging could hardly occur in all cases. The bearing of slagging on the fusing of concrete is still a question.

These observations tend to show that the Edison fire was the hottest ever recorded, and that it produced in some places temperatures approaching blast-furnace heat.

Farther on in the report the fused concrete in Building 12 is described as follows:

There is apparently no structural damage in the first and second stories of this building, which are in fair condition. There is some evidence of fused concrete at one point near the south wall.

In the basement, however, conditions are quite different. The ceiling, beams, girders, and columns supporting them in this lowest story show a remarkable appearance of fused concrete, especially in the floor panels toward the north side. Small stalactites of concrete hang down from the ceiling and large bunches of it adhere to the columns where it has run down and hardened. The lower part of three beams has wasted away, exposing the reinforcement, which has melted or burned out, causing failure of the beams. The under side of the floor slabs adjoining these beams has also wasted away, exposing the metal reinforcement, part of which has melted and hangs down in tapering rods, the area of which has been reduced in some cases to about one-eighth of its original size. The columns, in addition to being fused on the surface, have also spalled. The metal reinforcement of two columns only is exposed and distorted from expansion, the same as in the other buildings. One wall column on the south side has failed by shear.

This was undoubtedly the hottest place in the entire fire, the temperature probably being 2500° F. or more. Eyewitnesses state that the fire was burning here long after it had died down in the rest of the plant.

Suggested Itinerary for Engineers Desiring to Visit Reclamation Service Projects

For the benefit of any who may wish to visit the interesting dams and irrigation canal systems of some of the projects of the United States Reclamation Service on their way to or from the Panama-Pacific Exposition, the following itinerary, with prefatory comments, has been prepared for this journal through the courtesy of A. P. Davis, Chief Engineer of the United States Reclamation Service, Washington, D. C.

Prefatory Comments

In considering this itinerary it should be borne in mind that the southern projects in New Mexico and Arizona can be visited to best advantage in the spring or autumn. Those engineers intending to visit San Francisco before or even during May are advised to go by the southern route and return by the central or northern route. Those leaving in the summer should by all means go by the northern or central route, and, if delayed until autumn, return by the southern route.

In the three itineraries outlined, the first course suggested is to go from Chicago to the Southwest by El Paso, Phœnix and Yuma, and come east from San Francisco through Nevada and Utah.

The second, or summer, trip suggested is to go west, reversing the order of journey which in the first route covers the trip from San Francisco to Chicago, and then, in leaving San Francisco, to go toward the north by the Shasta route and visiting points in Washington and Idaho.

The third suggested trip is to leave Chicago going toward the Northwest instead of toward the West or Southwest, and practically repeating in reverse order the suggestion for the second trip, this being most advantageously taken during the middle of summer.

I. Going by southern route and returning by Salt Lake City:

First day—Leave Chicago.
Second—En route via Rock Island Railroad.
Third—Arrive El Paso, Tex., visit irrigation works in vicinity.
Fourth—Automobile or railroad trip to Elephant Butte Dam.
Fifth—Return to El Paso, Southern Pacific train to Phœnix, Ariz.
Sixth—Arrive Phœnix.
Seventh—Automobile through Salt River project to Roosevelt Dam.
Eighth—Return to Phœnix and see irrigation works in valley.
(As an alternative route, after leaving El Paso, change at Bowie, go to Globe, Ariz., and take automobile from Globe to Phœnix by way of the Roosevelt Dam).
Ninth—Phœnix to Yuma.
Tenth—Visit Laguna Dam. See headworks, main canal and siphon.
Eleventh—To Los Angeles. From there visit San Fernando hydraulic-fill dam being built by city.
Twelfth—At Los Angeles.
Thirteenth—At San Francisco.
Returning from San Francisco over the Ogden Route:
First day—6 p.m., San Francisco to Hazen, Nev.
Second—Automobile to Lahontan Dam. See some of the project and leave for Ogden, Utah.
Third—Arrive Ogden and Salt Lake City.
Fourth—To Provo; by automobile to Strawberry Valley Dam in mountains.
Fifth—Return and see construction of irrigation system.
Sixth—To Grand Junction, Colo.
Seventh—See dam being built on Grand River, tunnels and main canal.
Eighth—To Montrose; visit Gunnison Tunnel and part of distributing system.
Ninth—Leave for Denver.
Tenth—In Denver.
Eleventh—En route for Chicago.
Twelfth—Arrive Chicago.

II. From Chicago. Reverse latter part of above trip, taking 12 days from Chicago to San Francisco. On leaving San Francisco go north as follows:

First day—Leave San Francisco by Shasta route.
Second—Arrive Portland.
Third—Seattle.

Fourth—Visit large dams at head of Yakima River, getting off at Easton for Kachess Dam (completed) or at Meadow Creek for Keechelus Dam (under construction).
Fifth—Go over construction work.
Sixth—To North Yakima and Sunnyside Valley.
Seventh—To Spokane and visit water powers.
Eighth—Boise, Ida.
Ninth—To Arrowrock Dam, 350 ft. high, approaching completion.
Tenth—Deerflat Reservoir.
(As an alternative to going by Yakima Valley and Spokane, the trip can be made directly east from Portland to Boise, visiting the new diversion dam on Umatilla River en route).
Eleventh—Minidoka Project. Visit dam and power plant.
Twelfth—Pocatello and Butte.
Thirteenth—Helena and Great Falls.
Fourteenth—Sun River diversion dam and canals.
Fifteenth—En route east over Great Northern and Northern Pacific.

III. The above return trip may be reversed, leaving Chicago and going directly to Montana points or to Pocatello, Minidoka, Boise, Portland to San Francisco and coming east as in the first trip.

It is suggested that the various project engineers be notified in advance of any proposed visit to a given project. The names and addresses of any of these engineers may be obtained from the United States Reclamation Service, Washington, D. C.

News of the Engineering World

San Francisco Statistics

Area, City and County of San Francisco, square miles	46.5
Population	528,947
Paved streets, miles	400
Sewer system, miles	475
Number of schools	110
Assessed valuation	$647,104,534
Bank clearings for year 1914	$2,516,004,816
Value of building operations for year 1914	$30,369,361
Postal receipts for year 1914	3,252,306
Number of public parks	32
Acreage of public parks	1,800
Number of churches	220
Number of manufactories actually producing for the trade	2,375
Number of ships clearing from this port during 1914	5,870
Street railways, double track, miles	157

Patented Bridges in the Pennsylvania Legislature

A bill introduced in the Pennsylvania Senate provides special recognition for patented bridges. The bill requires that all competitive designs and specifications must be displayed for bidding. The chief clauses of the bill are:

They [the County Commissioners] shall cause to be prepared a survey and profile of location and a plan and specifications of the proposed work setting forth the required loading and water-discharge capacity of the bridge [and] shall expose [them] to public inspection for at least three weeks. . . .

If a bridge is to be constructed or is to be entirely rebuilt the commissioners shall accept any competitive designs and specifications therefor presented which they shall expose to public inspection for at least five days immediately prior to the time set for opening the bids. They shall consider bids or proposals upon such competitive designs and specifications but it shall not be lawful for them to make any contract based on any such design which does not comply with the general requirements of the survey profile plans and specifications which they have caused to be made or which has not been exposed to public inspection as above required. Any contract shall be unlawful which is based on any plan or specification calling for or making use of any patented process or patented design unless such design and specifications are accompanied by an offer in writing signed by the person owning or controlling the patented design or patented process or by his legal representative setting forth the terms upon which such patented design or process may be obtained or used by any successful bidder in constructing the bridge under such contract.

Chicago River Tunnel

A tunnel under the North Branch of the Chicago River at Ashland Ave. is proposed in connection with an extension of the street-car lines, and plans for two projects have been prepared by the City Engineer, John Ericson. From the river to Fullerton Ave., the line of Ashland Ave. is occupied by private property, and it is estimated that it will be cheaper to tunnel under this than to condemn land for opening the street. A tunnel with roadway and sidewalk in addition to the car tracks is estimated to cost $2,723,000, while one for street-car traffic only would cost $1,215,380. An alternative plan is to build a bridge at a cost of $630,000, but this would require the purchase of property to open up a new street connection.

New High-Tension Cables Over Carquinez Straits

The Pacific Gas & Electric Co., of San Francisco, recently added two aërial cables across the Straits of Carquinez in increasing the capacity of its high-tension transmission lines from the mountain power stations to Oakland. The first cables were slung 14 years ago when the Bay Counties Power Co., completed its 142-mile transmission system from Colgate (described at length in ENGINEERING NEWS, Oct. 3, 1901). This was pioneer work for which no precedents had been established.

The cables passed from concrete anchorages over towers which supported the span at 208 ft. minimum clearance above the water. At the towers the cables rested on sheave-frames supported by porcelain insulators; housed strain insulators were interposed between the cables and anchorages.

In rearranging the tower tops to carry six cables, the old construction has been adhered to except in the substitution of steel I-beams for wooden cross arms and a steel platform for the wooden sheave-frame support. The new anchorages differ from the old by substituting, for iron-frame micanite-barrier oil-filled strain insulators, six porcelain insulators on upright steel beams embedded in the concrete anchor blocks; each cable is connected through springs to a frame on the insulator caps.

Dayton Garbage Works

Bids for the equipment of the proposed municipally owned garbage-reduction works of Dayton, Ohio, will be received on Feb. 26. The plant will have a capacity of 50 tons a day. It will be located on the Cincinnati, Hamilton & Dayton R.R., 7 mi. south of Dayton and 1 mi. north of Whitfield. The city will construct the half-dozen buildings and the settling tanks with day labor, and may decide to install the equipment. The bids requested are for: Ten 5-ton digestors, 5x14 ft. "in the straight," for cooking and pressing by liquid pressure; one 4x10-ft. pressure tank; one direct-heat tankage drier, capable of evaporating 1500 to 2000 lb. per hr. of moisture; percolating equipment to treat 6 to 8 tons of garbage per charge; one steam drier for redrying tankage so as to reduce 12 to 15% of moisture to 5%; three 80-hp. tubular horizontal boilers to work under 125 lb. pressure; a 4x80-ft. steel stack. The equipment will be motor driven. The work is to be done under the Department of Public Service, of which J. E. Barlow is Director. G. C. Cummin is City Civil Engineer. S. E. Wilson is Superintendent of Garbage Disposal and, we understand, is directly responsible for the general design of the plant. Bidders will submit detailed designs for such equipment as they offer, subject to conformity to the general plans and to standard practice.

ENGINEERING SCHOOLS

Massachusetts Institute of Technology—The Technology Club of Rochester, N. Y., has provided funds for trying the experiment of a few tutor-advisors who shall meet the students every day and discuss any difficulties. The advisors are to be young men in close touch with the students. An advisor will have an open hour each day from 1 to 2 p.m. in the institute commons.

University of Cincinnati—The Bureau of City Tests during the past year tested nearly 1200 samples of miscellaneous materials—cement (450 cars), reinforcing steel, fire hose, lubricating oils, paint, sand, blankets, chemicals, etc. The Bureau's work increased 80% last year as more and more of the city departments came to depend on it. The efforts of the Bureau are generally accepted in a coöperative spirit by makers and dealers.

Worcester Polytechnic Institute—The 50th anniversary of the founding of the Institute will be celebrated June 6 to 10. The program includes the dedication of the Alumni Athletic Field, the annual commencement exercises, processions, a banquet, and other celebrations. President Woodrow Wilson was the commencement speaker 25 years ago and has signified his intention to be present on June 9. Col. George W. Goethals has also accepted an invitation. The committee in charge of the anniversary program is George I. Rockwood, Charles Baker and Zelotes W. Coombs, of Worcester.

The Code for Steam-Boiler Construction, which has been under preparation by a committee of the American Society of Mechanical Engineers for over two years, was reported in revised form to the Council of that Society on Feb. 15 and was accepted.

The Water-Works of Billings, Mont., were transferred from the Billings Water Co. to the city on Feb. 1, 1915, at a valuation of $315,000. A water-purification plant will be built and the mains extended at a cost of $135,000, the people having voted $450,000 bonds for water-works acquisition and improvement not long ago. Three commissioners, a superintendent at $200 and a cashier at $125 a month will manage the works.

A New Transcontinental Railway went into operation Feb. 6. This is a working combination of the St. Louis & San Francisco R.R. and the Santa Fé system. The new route will be via the St. Louis & San Francisco from New Orleans to Houston, Tex., and then over the Santa Fé to San Francisco, including the Coleman and Belen cut-offs in Texas and New Mexico. This will give New Orleans and the South two transcontinental railway lines, the other being the Southern Pacific system.

A Large Reinforced-Concrete Warehouse for railway and storage purposes is to be built at Chicago by the Midland Tranfer & Warehouse Co., which is a concern backed by the stock-yards interests. It will be located at Western Ave. and 15th St., and its second floor will have three tracks connecting with the elevated line of the Chicago Junction Ry. The building will be 260x405 ft., 58 ft. high, with four stories and basement. It will be of reinforced-concrete construction, on a flat-slab system, with floor panels 18 ft. 6 in. by 18 ft. 8 in c. to c. of columns. The floor loads are 400 lb. per sq.ft. for the first floor, 350 lb. for the second (with tracks), 300 lb. for the third and 250 lb. for the fourth. There will be six elevators of 8000 lb. capacity, besides electric hoists and "lowerators." The building was designed by S. Scott Joy, architect, and the general contractors are Stone & Webster. The entire plant will represent an investment of some $700,000, and it is to be ready for service by August, 1915.

Progress of Dorchester Tunnel, Boston—The Dorchester Tunnel is substantially completed from Tremont St. to the westerly side of Dewey Square, with the exception of the interior finish in the Washington station, which extends from Washington to Chauncy St. The work of finishing the station is nearing completion.

Section D includes a station under Dewey Square and about 450 ft. of tunnel under Summer St. east of the station. Work is now in progress on both station and tunnel. The Hugh Nawn Contracting Co. is the contractor.

Section E includes two single-track circular tunnels which will extend from near the junction of Summer St. and Dorchester Ave. under Fort Point Channel and private property to a point near Dorchester Ave. between West First and West Second St., South Boston. These tunnels will be driven by means of shields and with compressed air. Work has begun on the main shaft in West First St. P. McGovern & Co. are the contractors.—Journal of Boston Soc. C. E.

The Causes of Explosions in Sewers at Pittsburgh, Penn., are being studied by the United States Bureau of Mines in cooperation with the city. Special methods and apparatus have been devised to sample and test the air and many samples of sewer air have been examined. Gasoline has been introduced into sewers, with special precautions to prevent accidents, and the amounts of different kinds of gasoline necessary to produce explosive mixtures under different conditions have been determined. Studies are also being made regarding the intrusions of natural gas, artificial gas, washings from garages, residues from cleaning plants, etc. All possible sources of ignition are being studied. A report of the investigations will be published as soon as sufficient data have been obtained. The work is under the supervision of G. A. Burrell, chief gas chemist of the Bureau of Mines, and H. T. Boyd, chemist of the city of Pittsburgh, with the collaboration of other members of the staff of the Bureau of Mines and the Public Safety Department of the City of Pittsburg. —From U. S. Bureau of Mines.

California State Highways—Statistics of completed work on the state highways of California to Jan. 15, 1915, show that 2150 miles of surveys have been made, 1101 miles of roadway laid out, contracts let for 1008.5 miles, while 632 miles of road have been completed. There has been a tremendous impetus given to concrete road building on the west coast within the last year or two. In California during the last year no less than 270 miles of portland-cement concrete pavement were laid. Of this 208 miles were pavements 15 ft. wide. Only 6 miles were the minimum width of 12 ft.; 43 miles were 18 ft. wide; 8 miles 20 ft.; and 5 miles 24 ft. wide. The total mileage of cement-concrete roads under construction and completed is 685 miles, nearly all of which has a thin bituminous top. The rest, 21 miles, has an asphaltic top. The consumption of cement has increased by leaps and bounds, from 132,955 bbl. in 1912 to 572,066 bbl. in 1914. The state has constructed only 13 miles of waterbound macadam and 19 miles of oil macadam. The State Highway Engineer of California is Austin B. Fletcher, formerly of the Massachusetts State Highway Commission.

Four Optional Charter Forms for Massachusetts Cities have been framed by a joint committee of the legislature after a series of recess hearings. The four plans, prefaced by an interesting report, have recently been submitted to the legislature. Plan A provides for a council of nine members and a mayor, the latter to have full executive control of the city with absolute veto power of acts of the council and with absolute power of appointment and removal of all administrative officials. Plan B provides for a council of 11 to 14 members, according to the number of wards in the city, one member to be chosen from each of the wards and the other members to be chosen at large, and for a mayor with limited power of veto and with power of appointing city administrative officers subject to the approval of the council. Plan C is the commission plan with five commissioners, each selected to head a specific department of the city but the commission having authority to decide for itself what branches of city government shall be included in each department whenever a difference of opinion arises. Plan D is the now well-known commission-manager plan. Except under Plan B, all the councilmen would be elected at large.

A Municipal Motor-Bus System for Chicago has been proposed, and the city's budget for 1915 includes an appropriation of $3,000,000 for operating such a system. This sum would be taken from the "traction fund" built up from the city's 55% share of the profits of the street-railway companies. The franchise granted to these companies in 1907 provides that this fund shall be for the purchase and construction of the railways by the city, but the city's law department has rendered an opinion that this is not binding and that the city can dispose of the money as it chooses.

The purpose of the new transportation system is to afford additional facilities and reduce the present excessive crowding of the street cars, but it is objected that in the business district the motor-buses will simply add to the number of vehicles in streets already so crowded that movements are extremely slow and various steps are being considered for reducing the congestion. This congestion, with its slow traffic movement, is one of the main arguments for the proposed street-car subways through the business district.

Private companies have applied for permission to operate in the streets, but no authority has been given to any of these. Other companies desire to operate in the parks and boulevards, where no public system of transportation exists. The action of the city council is not necessary in such cases, as the parks and boulevards are under the control of the different park commissions. The South Park Commission has already granted a permit to one company.

The Life Savers of the U. S. Bureau of Mines have rescued over 100 entombed miners from certain death, according to a statement of J. A. Holmes, Director, in his annual report. The Bureau now maintains six mine-rescue stations, eight mine-rescue cars and one motor truck, all located in the mining districts of the country. The cars visit the various mining camps, and train the men in rescue work and also in first aid to the injured. Whenever there is a mine disaster, it is now possible to obtain a sufficient number of trained volunteers to take care of the rescue in an orderly and systematic manner, and without the great loss of life so frequently found among the rescuers in the past. In the relatively short period during which the crews of the bureau's rescue cars and stations have been able to conduct active training of miners, 46,694 men have visited the cars and stations, 26,229 have attended lectures and safety demonstrations, 2826 were given mine-rescue training and 5780 received first-aid instruction and rescue training. The states are spending for inspection and police supervision more than the Federal Government in all its safety investigations. Pennsylvania maintains a well organized inspection force at an annual cost of $213,000. More than 170 mining companies have individually or through association established 76 mine-rescue stations at which there are 1200 sets of rescue apparatus, besides the auxiliary equipment for first-aid and fire-fighting work. There are also 12 mine-rescue cars now operated by individual companies about their own properties.

The Appraisal of Public Utilities in Indiana, by the engineering staff of the Public Service Commission, since June, 1913, has covered 29 utilities representing a total cost (new) of $14,400,000. These include six electric light and power utilities (three utilizing their exhaust steam for heating plants), $8,045,000; eight water plants, $2,785,000; eight telephone plants, $1,075,000; two gas-manufacturing plants, $2,030,000; three natural-gas plants, $225,000; and two hot-water heating plants, $215,000. The cost to the utilities for their appraisals (with audits and attorneys' fees) has been estimated at $101,000, and the cost of the appraisal work by the engineering staff of the Commission has been about 20% of this amount. The staff now has property in hand, upon which reports will be made within six months, to the amount of about $10,000,000. The general practice is for the utility to furnish the Commission with a detailed inventory prepared by an appraisal company. This is checked by the engineering staff, and then summarized and priced. A copy of this appraisal is then furnished to each of the contending parties (usually the utility and the city), and a public hearing is held. The greatest bone of contention is always the question of intangible values. The appraisal work for the utilities is done mostly by engineers from outside the state, and the work for municipalities by home engineers. The work of appraisal does not seem to suffer in time of general depression, disagreements between consumers and utility managements being about as frequent at one time as another. The above is condensed from a report presented at the annual meeting of the Indiana Engineering Society, Jan. 22, by H. O. Garman, Chief Engineer of the Public Utility Commission of Indiana.

Sewage Disposal for a Group of Cities in northern Indiana by means of a connection with the Chicago Drainage Canal has been defeated, owing to failure of the cities to vote unanimously in favor of the organization of a sanitary district to represent their interests jointly. The pollution of Lake Michigan by the growing manufacturing cities and industrial district at its southwest corner is a serious condition, and various plans have been considered for the disposition and treatment of the sewage. The problem should be treated as a unit, but there has been difficulty in getting the cities interested to work in harmony, and the city of Hammond alone has been planning a sewage-disposal system estimated to cost $600,000.

A sanitary district comprising the several cities and towns in the Calumet River territory was proposed, and in 1913 the Indiana legislature passed a bill authorizing the organization of such a district, subject to a referendum to the voters of each city. The Sanitary District of Chicago then made a proposition to have the sewage of the proposed Northern Indiana Sanitary District disposed of by means of the new Sag Canal and the Chicago Drainage Canal. It also promoted the organization of the proposed district, in order that it might have some definite authority to deal with, instead of dealing with several minor and partly antagonistic authorities.

The county commissioners of Lake County, Indiana, secured petitions for the proposed district for the four cities of Hammond, East Chicago, Gary and Whiting, and the vote was taken on Jan. 30. The project lost by about 2000 to 1500, the first two cities voting against it and the other two in favor of it. The vote was light, only about 20,000 out of a population of 100,000. Fear of high taxes is thought to have been the reason for the adverse vote. Under the law the project required the favorable vote of each city. A joint commission of mayors and public officials of the four cities issued a report in favor of the project. Dr. W. D. Weis, of Hammond, Ind., is secretary of this commission.

PERSONALS

Prof. Hermon C. Bumpus, President of Tufts College, has been appointed a member of the City Planning Board of Somerville, Mass. The other members of the Board are Messrs. E. W. Bailey, City Engineer; A. M. Pinkham, W. E. Dodge and A. S. Heald.

Mr. R. C. Andrews, Division Superintendent of the Texas & Pacific Ry., at Marshall, Tex., has been appointed Assistant General Superintendent, with headquarters at Dallas, Tex. Mr. William Lynch, Superintendent of the New Orleans Division, succeeds Mr. Andrews.

Messrs. J. B. Lippincott, M. Am. Soc. C. E., Consulting Engineer, of Los Angeles, Calif., and M. M. O'Shaughnessy, M. Am. Soc. C. E., City Engineer of San Francisco, have been appointed by the City of San Diego to review the available water-supply and investigate the cost of additional development for that city. Mr. Lippincott was formerly Assistant Chief Engineer of the Los Angeles Aqueduct.

Mr. R. W. Bonney, who has been connected with the Valuation Department of the Norfolk Southern R.R., has entered the employ of the Newport News Shipbuilding & Dry Dock Co., of Newport News, Va. He will be connected with the civil engineering department and will take charge of yard surveys. Mr. Bonney was formerly with the United States Government on the inland waterways survey from Norfolk, Va., to Beaufort, N. C.

Mr. Everett M. Breed, M. Am. Inst. E. E., for the past eight years District Manager of the Canadian Allis-Chalmers Co., Ltd., at Vancouver, B. C., has been appointed District

Manager of the Pelton Water Wheel Co., of San Francisco, Calif., will continue his headquarters at Vancouver. Mr. Breed is a graduate of the University of Maine. Previous to his connection with the Canadian Allis-Chalmers Co., Ltd., he was with the sales department of the Canadian Westinghouse Co., at Montreal, Que.

Mr. Henry C. McRae, Assoc. M. Soc. C. E., Division Engineer of the Baltimore (Md.) Sewerage Commission, has been appointed District Engineer of the Detroit District of the International Joint Commission. The work involves cost studies of the problem of collecting, transporting and treating the sewage of Detroit and nearby cities, the object being to relieve the pollution of the Detroit and St. Clair Rivers. The work is under the general direction of Prof. Earle B. Phelps, Assoc. Am. Soc. C. E., Consulting Engineer for the International Joint Commission.

OBITUARY

James Finney McElroy, M. Am. Soc. M. E., President of the Consolidated Car Heating Co., of Albany, N. Y., died at Laconia, N. H., Feb. 10. Mr. McElroy was born in Greenfield, Ohio, Nov. 25, 1852, and graduated from Dartmouth College in 1876. For four years after his graduation Mr. McElroy was principal teacher of the Indianapolis Institution for the Blind, and for seven succeeding years was Superintendent of the Michigan Institution for the Blind. Mr. McElroy organized in 1887 the McElroy Car Heating Co., which two years later was combined with the Sewall Car Heating Co.

Frank Olin Marvin, M. Am. Soc. C. E., Dean of the School of Engineering of the University of Kansas, died at San Diego, Calif., Feb. 6, from heart disease, in his 63d year. Professor Marvin was connected with the University of Kansas for 40 years. In 1891 he reorganized the engineering courses into a school distinct from the rest of the University. In appreciation of his long service in the advancement of engineering education at the University, a bronze bust of Professor Marvin was recently presented to the University by a number of his former students. Dean Marvin retired from active work last year.

ENGINEERING SOCIETIES

COMING MEETINGS

MINNESOTA SURVEYORS AND ENGINEERS SOCIETY.
Feb. 19-20. Annual meeting, at St. Paul, Minn. Secy., George H. Herrold, City Hall, St. Paul, Minn.

INDIANA SANITARY AND WATER SUPPLY ASSOCIATION.
Feb. 23-24. Annual meeting at Indianapolis, Ind. Secy., Dr. W. F. King, State Board of Health, Indianapolis, Ind.

ILLINOIS WATER SUPPLY ASSOCIATION.
Mar. 9-11. Annual convention at University of Illinois. Secy., Edward Bartow, Urbana, Ill.

AMERICAN RAILWAY ENGINEERING ASSOCIATION.
Mar. 16-18. Annual meeting at Chicago, Ill. Secy., E. H. Fritch, 900 So. Michigan Ave., Chicago, Ill.

Iowa State Drainage Association—The annual meeting will be held at Webster City, Iowa, Feb. 25-26. The Secretary is H. M. Sparboe, Webster City.

The International Congress of Navigation—The Thirteenth International Navigation Congress was to have been held in Stockholm, Sweden, during the coming summer. The Swedish Government, under date of Jan. 12, announced that the Congress would be indefinitely postponed.

Louisiana Engineering Society—At a meeting of the Society on Feb. 8, the annual address of President Williams, entitled "The Ethics of the Contractor," was discussed by a number of members. The Secretary is W. T. Hogg, Museum Bldg., Chartres and Ann Sts., New Orleans, La.

American Institute of Consulting Engineers—The officers for the ensuing year are: President, Elmer L. Corthell; Vice-President, Charles Sooysmith; Secretary, F. A. Molitor, 35 Nassau St., New York City. Vacancies in the Council have been filled by Allen Hazen, George Gibbs and Charles E. Lucke, all of New York City.

Boston Engineers' Annual Dinner—The sixth annual dinner of the engineering societies of Boston was held at the new City Club on Feb. 15, with about 275 in attendance. J. W. Rollins acted as toastmaster, and Governor Walsh, of Massachusetts, was the guest of honor. Addresses were made by Charles Whiting Baker, editor-in-chief of "Engineering News," on "The Broader Civic Relationships of the Engineer," and by Capt. Robert Bartlett, on Arctic exploration.

Indiana Sanitary and Water Supply Association—The eighth annual meeting will be held in affiliation with the Indiana State Board of Health at the Hotel Severin, Indianapolis, Ind., Feb. 23-24. Among the various papers to be presented are the following: "Water Waste Elimination," Paul Lanham, Pitometer Operator, Water Department, Washington, D. C.; "The Standards for Water Used on Interstate Carriers," H. E. Jordan, Superintendent of Filtration, Indianapolis Water Co.; "Treatment of Industrial Waste," Langdon Pearse, Engineer, Sanitary District of Chicago; "Stream Sanitation," Earle B. Phelps, Professor of Chemistry, U. S. Public Health Service, Washington, D. C.; "The Indianapolis Experimental Sewage Disposal Plant," C. H. Underwood, City Chemist, Indianapolis. There will be a visit to the new pumping station of the Indianapolis Water Co. The annual banquet will be held on Feb. 23, and a luncheon on Feb. 24. The Secretary is W. F. King.

Minnesota Surveyors and Engineers Society—The annual meeting will be held Feb. 19-20, at St. Paul, Minn., with headquarters at the Ryan Hotel. Among the papers scheduled for presentation are the following: "Keeping of Costs by the Engineer," O. H. Mann, District Engineer, Highway Commission, Moorhead; "Roseau River Drainage Project," E. V. Willard, State Drainage Engineer, St. Paul; "The Drainage Engineer and the Public Road," S. L. Kennedy, Deputy County Surveyor, Princeton; "Segmental Vitrified Sewer Pipe," William Danforth, Municipal Contracting Engineer, St. Paul; "Aims and Purposes of the League of Minnesota Municipalities," Prof. R. R. Price, Secretary; "Bridges in Minnesota," C. E. Nagel, Deputy Engineer of Bridges, State Highway Commission; "Some Features of Stadia Surveying and Its Broader Uses," W. B. Saunders, Consulting Engineer, Minn.; "Practical Garbage Disposal for Small Cities," E. W. Kibbey, Civil Engineer, International Falls; "Sewage Pumping Plant at Park Point, Duluth," John Wilson, City Engineer, Duluth; "Central Heating Plants for Small Towns," J. F. Druar, St. Paul; "Sewage Disposal for Small Towns," L. A. Rowat, Willmar. A dinner and smoker will be held on Feb. 20. The Secretary is George H. Herrold, City Hall, St. Paul.

New England Water Works Association—At the monthly meeting of the New England Water Works Association, held in Boston on Feb. 10, the reports of two committees were discussed. William F. Sullivan, Vice-President, presiding in the absence of President Leonard Metcalf, first called on X. H. Goodnough to discuss the report of the Committee on Yield of Drainage Areas, of which F. P. Stearns is Chairman. Mr. Goodnough spoke at some length on the question of underground storage and was followed by W. S. Johnson, who called attention to the need of data on the yield of swamp areas to make the report complete.

Great interest was shown in the report of the Committee on Meter Rates, which was discussed by many members of the Association. The main parts of the report were: Divisions of the Sliding Scale, Amount of Slide in the Scale, Service Charges and Unit of Measurement.

The recommendations of the committee, that there be three divisions in the sliding scale, brought out some interesting accounts of its application and showed that some cities have sold water to large consumers on the third schedule at less than cost, a practice which appears not to have been justified in the long run since the very success of that means of obtaining customers has led to greater plant requirements without increasing income to a commensurate degree. Mr. Hazen, for the committee, pointed out that there was nothing in the proposed schedules to prevent making two or even all three of the rates equal and that no definite charges were recommended for any of them.

Under Service Charges the committee referred to the loss on metered services due to the inability of meters to register small flows. C. W. Sherman made the point that not all unaccounted-for water goes through the service meters; some of it leaks out of the mains. As an example he referred to conditions in Belmont, Mass., where water is obtained from the Metropolitan System through a Venturi meter and where all services, even those supplying water for flushing, are metered. The leakage is therefore readily determined and its amount has to be considered in making rates.

The manner of making the service charge in a town having a considerable summer colony in addition to its permanent population was the subject of some discussion, as it is a problem which has caused trouble to the water boards of a number of such places.

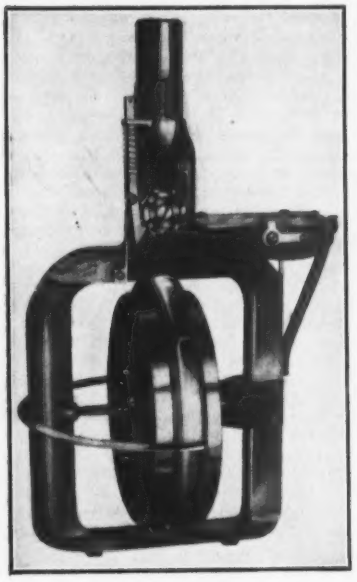
A vote was taken on the preference of those present for the use of gallons or cubic feet as the unit of measurement by meter. A large majority preferred the former unit.

The report of the Committee on Statistics of Water Purification Plants, which was scheduled for discussion at this meeting, was not reached and it will be discussed at the March meeting.

Appliances and Materials

Improved Fteley-Stearns Current Meter

The accompanying illustration shows the most recent development of the Fteley-Stearns type of current meter, embodying improvements suggested by A. T. Safford, Consulting Hydraulic Engineer, Lowell, Mass. It has noncorrosive iridium bearings which are nearly frictionless; the rear bearing is specially protected against sawdust, etc. The wheel is heavier than in previous instruments of this type, is 5 in. in diameter instead of 3½ in., and has six vanes instead of eight; the pitch of the wheel is 2.3 ft. The axle is extra heavy and the wheel stronger and stiffer so as to withstand velocities as high as 13 ft. per sec. Special attention is given to rigidity of the meter as a whole, by carrying a horizontal beveled bar around in front of the wheel, securely fastened at both ends to the circular bar inclosing the wheel. All this framework is made of very thin knife-edge blades. The automatic counter is driven by inclosed bevel gears. The counter-box is reinforced and protected by the rod brace as shown.



LATEST FTELEY-STEARNS CURRENT METER

It is claimed that the meter begins to record at a flow of 0.1 ft. per sec., and is accurate from 0.2 ft. per sec. The Fteley-Stearns type of meter is made by the Buff & Buff Mfg. Co., Boston, Mass., and this newest model, No. 8, is listed at $151.

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One-Ton Packard Motor Truck

The light-duty motor-truck field has been entered by the Packard Motor Car Co., of Detroit, Mich., with a 1-ton vehicle. The company's line now runs from one to six tons capacity. The same general features of design are employed throughout, including worm drive, electric starting and lighting, carburetor for low-grade fuel, speed-limit governor, protected wiring, etc.

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Double-Cage Tunnel Hoists

The electric hoists for the construction shafts of the Mill Creek sewer tunnel at St. Louis, Mo., have the special feature of a double brake, equalized so that the operator has the same control of the load in either direction. Double-cage hoists of this type have been designed generally with a single brake band, which has given good braking efficiency only with the hoist running in one direction.

The new hoists are equipped with 82-hp. motors running at 514 r.p.m. The usual contactor-panel control, the cost of which is almost prohibitive for contractor's work, has been replaced by a carbon-disk system. With this controller the resistance is regulated by the compression of graphite disks, and arcs are reduced to the minimum. These hoists were built by the Thomas Elevator Co., of Chicago. The Mill Creek sewer tunnel project was described in our issue of Sept. 3, 1914.

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Concrete Mixer-Distributor for Road Work

The improved outfit for mixing and placing concrete in road work shown in the accompanying illustration has been designed by the Municipal Engineering & Contracting Co., of Chicago. A mixer, engine, charging skip, and horizontal boom with dumping bucket are all mounted on a steel frame. The heavier end of the machine is carried by a pair of caterpillars 2 ft. wide and 5 ft. long. The load on the front wheels is sufficient for steering. The drive comprises a differential gear and the machine can turn around in about its own length.

Another feature is an automatic dumping bucket. This is of approximately semicylindrical form, but has one end inclined and so hung that, when unlatched from the bail, the weight of concrete will tilt it. When the loaded bucket has been run out to the point where it is to be dumped, the operator reverses the travel, which unlatches the bucket, causing it to invert and dump; the bucket then automatically rights itself, latches and returns. The 20-ft. boom is power swung through 160°, so that concrete can be spread over a width of 40 ft. The charging skip lies on the ground for loading from wheelbarrows, and in its delivering position it stands vertical.

With a steam-power equipment two men are required, one to handle the charging skip and the other to handle the dump bucket and attend to the firing. The mixer is set at such a height that the concrete can be discharged into carts if desired. The machine is made in two sizes, one with a ½-yd. mixer and weighing about 5 tons; the other with a ½-yd. mixer and weighing about 7½ tons. These are reported to have laid over 1000 and 1400 sq.yd., respectively, of 6-in. concrete per working day.

CONCRETE MIXER-DISTRIBUTOR FOR STREET PAVING